

4303. The mixture of claim 4285, wherein the condensable hydrocarbons further comprises oxygenated hydrocarbons, and wherein greater than about 5 % by weight of the condensable hydrocarbons comprises the oxygenated hydrocarbon.

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4304. The mixture of claim 4285, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise  $H_2$ , wherein greater than about 5 % by weight of the non-condensable hydrocarbons comprises  $H_2$ .

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4305. The mixture of claim 4285, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise  $H_2$ , wherein greater than about 15 % by weight of the non-condensable hydrocarbons comprises  $H_2$ .

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4306. The mixture of claim 4285, wherein a weight ratio of hydrocarbons having greater than about 2 carbon atoms, to methane, is greater than about 0.3.

4307. A mixture produced from a portion of a hydrocarbon containing formation, comprising:

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condensable hydrocarbons, wherein less than about 15 % by weight of the condensable hydrocarbons have a carbon number greater than about 25;

wherein less than about 1 % by weight of the condensable hydrocarbons, when calculated on an atomic basis, is nitrogen;

wherein less than about 1 % by weight of the condensable hydrocarbons, when calculated on an atomic basis, is oxygen; and

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wherein less than about 1 % by weight of the condensable hydrocarbons, when calculated on an atomic basis, is sulfur.

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4308. The mixture of claim 4307, further comprising non-condensable hydrocarbons, wherein the non-condensable component comprises hydrocarbons having carbon numbers of less than 5, and wherein a weight ratio of hydrocarbons having carbon numbers from 2 through 4, to methane, is greater than approximately 1.

4309. The mixture of claim 4307, wherein the condensable hydrocarbons further comprise olefins, and wherein about 0.1 % by weight to about 15 % by weight of the condensable hydrocarbons are olefins.

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4310. The mixture of claim 4307, further comprising non-condensable hydrocarbons, and wherein a molar ratio of ethene to ethane in the non-condensable hydrocarbons ranges from about 0.001 to about 0.15.

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4311. The mixture of claim 4307, wherein the condensable hydrocarbons further comprise oxygen containing compounds, wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

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4312. The mixture of claim 4307, wherein the condensable hydrocarbons further comprise aromatic compounds, and wherein greater than about 20 % by weight of the condensable hydrocarbons are aromatic compounds.

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4313. The mixture of claim 4307, wherein the condensable hydrocarbons further comprise multi-ring aromatics, and wherein less than about 5 % by weight of the condensable hydrocarbons comprises multi-ring aromatics with more than two rings.

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4314. The mixture of claim 4307, wherein the condensable hydrocarbons further comprise asphaltenes, and wherein less than about 0.3 % by weight of the condensable hydrocarbons are asphaltenes.

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4315. The mixture of claim 4307, wherein the condensable hydrocarbons further comprise cycloalkanes, and wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons are cycloalkanes.

4316. The mixture of claim 4307, further comprising non-condensable hydrocarbons, ~~and wherein the non-condensable hydrocarbons comprise hydrogen, and wherein greater than about 10 % by volume and less than about 80 % by volume of the non-condensable component comprises hydrogen.~~

4317. The mixture of claim 4307, further comprising ammonia, and wherein greater than about 0.05 % by weight of the produced mixture is ammonia.

4318. The mixture of claim 4307, further comprising ammonia, and wherein the ammonia is used to produce fertilizer.

4319. The mixture of claim 4307, wherein the condensable component further comprises olefins, and wherein about 0.1 % to about 5 % by weight of the condensable component comprises olefins.

4320. The mixture of claim 4307, wherein the condensable component further comprises olefins, and wherein about 0.1 % to about 2.5 % by weight of the condensable component comprises olefins.

4321. The mixture of claim 4307, wherein the condensable hydrocarbons further comprise oxygenated hydrocarbons, and wherein greater than about 5 % by weight of the condensable hydrocarbons comprises oxygenated hydrocarbons.

4322. The mixture of claim 4307, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise  $H_2$ , and wherein greater than about 5 % by weight of the non-condensable hydrocarbons comprises  $H_2$ .

4323. The mixture of claim 4307, further comprising ~~non-condensable hydrocarbons,~~ wherein the non-condensable hydrocarbons comprise  $H_2$ , and wherein greater than about 15 % by weight of the non-condensable hydrocarbons comprises  $H_2$ .

~~4324. The mixture of claim 4307, further comprising non-condensable hydrocarbons, wherein a weight ratio of compounds within the non-condensable hydrocarbons having greater than about 2 carbon atoms, to methane, is greater than about 0.3.~~

5 4325. A mixture produced from a portion of a hydrocarbon containing formation,  
comprising:

condensable hydrocarbons, wherein less than about 15 % by weight of the condensable hydrocarbons have a carbon number greater than 20; and wherein the condensable hydrocarbons comprise olefins, wherein an olefin content of the condensable component is less than about 10 % by weight of the condensable component.

4326. The mixture of claim 4325, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise hydrocarbons having carbon numbers of less than 5, and wherein a weight ratio of hydrocarbons having carbon numbers from 2 through 4, to methane, is greater than approximately 1.

4327. The mixture of claim 4325, wherein the condensable hydrocarbons further  
comprise olefins, and wherein about 0.1 % by weight to about 15 % by weight of the  
condensable hydrocarbons are olefins.

4328. The mixture of claim 4325, further comprising non-condensable hydrocarbons, and wherein a molar ratio of ethene to ethane in the non-condensable hydrocarbons ranges from about 0.001 to about 0.15.

4329. The mixture of claim 4325, wherein the condensable hydrocarbons further comprise nitrogen, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is nitrogen.

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4330. The mixture of claim 4325, wherein the condensable hydrocarbons further comprise oxygen, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is oxygen.

4331. The mixture of claim 4325, wherein the condensable hydrocarbons further comprise sulfur, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is sulfur.

4332. The mixture of claim 4325, wherein the condensable hydrocarbons, wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

4333. The mixture of claim 4325, wherein the condensable hydrocarbons further comprise aromatic compounds, and wherein greater than about 20 % by weight of the condensable hydrocarbons are aromatic compounds.

4334. The mixture of claim 4325, wherein the condensable hydrocarbons further comprise multi-ring aromatics, and wherein less than about 5 % by weight of the condensable hydrocarbons comprises multi-ring aromatics with more than two rings.

4335. The mixture of claim 4325, wherein the condensable hydrocarbons further comprise asphaltenes, and wherein less than about 0.3 % by weight of the condensable hydrocarbons are asphaltenes.

4336. The mixture of claim 4325, wherein the condensable hydrocarbons further comprise cycloalkanes, and wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons are cycloalkanes.

4337. The mixture of claim 4325, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprises hydrogen, and wherein the

hydrogen is about 10 % by volume to about 80 % by volume of the non-condensable hydrocarbons.

4338. The mixture of claim 4325, further comprising ammonia, wherein greater than about 0.05 % by weight of the produced mixture is ammonia.

4339. The mixture of claim 4325, further comprising ammonia, and wherein the ammonia is used to produce fertilizer.

4340. The mixture of claim 4325, wherein about 0.1 % to about 5 % by weight of the condensable component comprises olefins.

4341. The mixture of claim 4325, wherein about 0.1 % to about 2 % by weight of the condensable component comprises olefins.

4342. The mixture of claim 4325, wherein the condensable component further comprises oxygenated hydrocarbons, and wherein greater than about 1.5 % by weight of the condensable component comprises oxygenated hydrocarbons.

4343. The mixture of claim 4325, wherein the condensable component further comprises oxygenated hydrocarbons, and wherein greater than about 25 % by weight of the condensable component comprises oxygenated hydrocarbons.

4344. The mixture of claim 4325, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise  $H_2$ , and wherein greater than about 5 % by weight of the non-condensable hydrocarbons comprises  $H_2$ .

4345. The mixture of claim 4325, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise  $H_2$ , and wherein greater than about 15 % by weight of the non-condensable hydrocarbons comprises  $H_2$ .

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4346. The mixture of claim 4325, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise hydrocarbons having carbon numbers of less than 5, and wherein a weight ratio of hydrocarbons having carbon numbers from 2 through 4, to methane, is greater than approximately 0.3.

4347. A mixture produced from a portion of a hydrocarbon containing formation, comprising:  
condensable hydrocarbons, wherein less than about 5 % by weight of the condensable hydrocarbons comprises hydrocarbons having a carbon number greater than about 25; and  
wherein the condensable hydrocarbons further comprise aromatic compounds, wherein more than about 20 % by weight of the condensable hydrocarbons comprises aromatic compounds.

4348. The mixture of claim 4347, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise hydrocarbons having carbon numbers of less than 5, and wherein a weight ratio of hydrocarbons having carbon numbers from 2 through 4, to methane, is greater than approximately 1.

4349. The mixture of claim 4347, wherein the condensable hydrocarbons further comprise olefins, and wherein about 0.1 % by weight to about 15 % by weight of the condensable hydrocarbons are olefins.

4350. The mixture of claim 4347, further comprising non-condensable hydrocarbons, wherein a molar ratio of ethene to ethane in the non-condensable hydrocarbons ranges from about 0.001 to about 0.15.

4351. The mixture of claim 4347, wherein the condensable hydrocarbons further comprise nitrogen, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is nitrogen.

4352. The mixture of claim 4347, wherein the condensable hydrocarbons further comprise oxygen, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is oxygen.

5 4353. The mixture of claim 4347, wherein the condensable hydrocarbons further comprise sulfur, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is sulfur.

10 4354. The mixture of claim 4347, wherein the condensable hydrocarbons further comprise oxygen containing compounds, wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

15 4355. The mixture of claim 4347, wherein the condensable hydrocarbons further comprise multi-ring aromatics, and wherein less than about 5 % by weight of the condensable hydrocarbons comprises multi-ring aromatics with more than two rings.

20 4356. The mixture of claim 4347, wherein the condensable hydrocarbons further comprise asphaltenes, and wherein less than about 0.3 % by weight of the condensable hydrocarbons are asphaltenes.

25 4357. The mixture of claim 4347, wherein the condensable hydrocarbons comprise cycloalkanes, and wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons are cycloalkanes.

30 4358. The mixture of claim 4347, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise hydrogen, and wherein the hydrogen is greater than about 10 % by volume and less than about 80 % by volume of the non-condensable hydrocarbons.



4359. The mixture of claim 4347, further comprising ammonia, and wherein greater than about 0.05 % by weight of the produced mixture is ammonia.

4360. The mixture of claim 4347, further comprising ammonia, and wherein the ammonia is used to produce fertilizer.

4361. The mixture of claim 4347, wherein the condensable hydrocarbons further comprise olefins, and wherein about 0.1 % to about 5 % by weight of the condensable hydrocarbons comprises olefins.

4362. The mixture of claim 4347, wherein the condensable hydrocarbons further comprises olefins, and wherein about 0.1 % to about 2 % by weight of the condensable hydrocarbons comprises olefins.

4363. The mixture of claim 4347, wherein the condensable hydrocarbons further comprises multi-ring aromatic compounds, and wherein less than about 2 % by weight of the condensable hydrocarbons comprises multi-ring aromatic compounds.

4364. The mixture of claim 4347, wherein the condensable hydrocarbons comprises oxygenated hydrocarbons, and wherein greater than about 1.5 % by weight of the condensable hydrocarbons comprises oxygenated hydrocarbons.

4365. The mixture of claim 4347, wherein the condensable hydrocarbons comprises oxygenated hydrocarbons, and wherein greater than about 25 % by weight of the condensable component comprises oxygenated hydrocarbons.

4366. The mixture of claim 4347, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise  $H_2$ , and wherein greater than about 5 % by weight of the non-condensable hydrocarbons comprises  $H_2$ .

4367. The mixture of claim 4347, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise  $H_2$ , and wherein greater than about 15 % by weight of the non-condensable hydrocarbons comprises  $H_2$ .

4368. The mixture of claim 4347, further comprising non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprises hydrocarbons having carbon numbers of less than 5, and wherein a weight ratio of hydrocarbons having carbon numbers from 2 through 4, to methane, is greater than approximately 0.3.

4369. A mixture produced from a portion of a hydrocarbon containing formation, comprising:

non-condensable hydrocarbons comprising hydrocarbons having carbon numbers of less than about 5, wherein a weight ratio of the hydrocarbons having carbon number from 2 through 4, to methane, in the mixture is greater than approximately 1;

wherein the non-condensable hydrocarbons further comprise  $H_2$ , wherein greater than about 15 % by weight of the non-condensable hydrocarbons comprises  $H_2$ ; and condensable hydrocarbons, comprising:

oxygenated hydrocarbons, wherein greater than about 1.5 % by weight of the condensable hydrocarbons comprises oxygenated hydrocarbons;

olefins, wherein less than about 10 % by weight of the condensable hydrocarbons comprises olefins; and

aromatic compounds, wherein greater than about 20 % by weight of the condensable hydrocarbons comprises aromatic compounds.

4370. The mixture of claim 4369, wherein the non-condensable hydrocarbons further comprise ethene and ethane, and wherein a molar ratio of ethene to ethane in the non-condensable hydrocarbons ranges from about 0.001 to about 0.15.

4371. The mixture of claim 4369, wherein the condensable hydrocarbons further comprise nitrogen, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is nitrogen.

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4372. The mixture of claim 4369, wherein the condensable hydrocarbons further comprise oxygen, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is oxygen.

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4373. The mixture of claim 4369, wherein the condensable hydrocarbons further comprise sulfur, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is sulfur.

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4374. The mixture of claim 4369, wherein the condensable hydrocarbons further comprise oxygen containing compounds, wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

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4375. The mixture of claim 4369, wherein the condensable hydrocarbons comprise multi-ring aromatics, and wherein less than about 5 % by weight of the condensable hydrocarbons comprises multi-ring aromatics with more than two rings.

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4376. The mixture of claim 4369, wherein the condensable hydrocarbons comprise asphaltenes, and wherein less than about 0.3 % by weight of the condensable hydrocarbons are asphaltenes.

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4377. The mixture of claim 4369, wherein the condensable hydrocarbons comprise cycloalkanes, and wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons are cycloalkanes.

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4378. The mixture of claim 4369, wherein the non-condensable hydrocarbons further comprises hydrogen, and wherein greater than about 10 % by volume and less than about 80 % by volume of the non-condensable hydrocarbons.

4379. The mixture of claim 4369, further comprising ammonia, and wherein greater than about 0.05 % by weight of the produced mixture is ammonia.

4380. The mixture of claim 4369, further comprising ammonia, and wherein the ammonia is used to produce fertilizer.

4381. The mixture of claim 4369, wherein the condensable hydrocarbons further comprise hydrocarbons having a carbon number of greater than approximately 25, wherein less than about 15 % by weight of the hydrocarbons have a carbon number greater than approximately 25.

4382. The mixture of claim 4369, wherein about 0.1 % to about 5 % by weight of the condensable hydrocarbons comprises olefins.

4383. The mixture of claim 4369, wherein about 0.1 % to about 2 % by weight of the condensable hydrocarbons comprises olefins.

4384. The mixture of claim 4369, wherein greater than about 25 % by weight of the condensable hydrocarbons comprises oxygenated hydrocarbons.

4385. The mixture of claim 4369, wherein the mixture comprises hydrocarbons having greater than about 2 carbon atoms, and wherein the weight ratio of hydrocarbons having greater than about 2 carbon atoms to methane is greater than about 0.3.

4386. A mixture produced from a portion of a hydrocarbon containing formation, comprising:

condensable hydrocarbons, wherein less than about 5 % by weight of the condensable hydrocarbons comprises hydrocarbons having a carbon number greater than about 25;

wherein the condensable hydrocarbons further comprise:

oxygenated hydrocarbons, wherein greater than about 5 % by weight of  
the condensable hydrocarbons comprises oxygenated hydrocarbons;

olefins, wherein less than about 10 % by weight of the condensable  
hydrocarbons comprises olefins; and

aromatic compounds, wherein greater than about 30 % by weight of the  
condensable hydrocarbons comprises aromatic compounds; and

non-condensable hydrocarbons comprising  $H_2$ , wherein greater than about 15 %  
by weight of the non-condensable hydrocarbons comprises  $H_2$ .

4387. The mixture of claim 4386, wherein the non-condensable hydrocarbons further  
comprises hydrocarbons having carbon numbers of less than 5, and wherein a weight  
ratio of hydrocarbons having carbon numbers from 2 through 4, to methane, is greater  
than approximately 1.

4388. The mixture of claim 4386, wherein the non-condensable hydrocarbons comprise  
ethene and ethane, and wherein a molar ratio of ethene to ethane in the non-condensable  
hydrocarbons ranges from about 0.001 to about 0.15.

4389. The mixture of claim 4386, wherein the condensable hydrocarbons further  
comprise nitrogen, and wherein less than about 1 % by weight, when calculated on an  
atomic basis, of the condensable hydrocarbons is nitrogen.

4390. The mixture of claim 4386, wherein the condensable hydrocarbons further  
comprise oxygen, and wherein less than about 1 % by weight, when calculated on an  
atomic basis, of the condensable hydrocarbons is oxygen.

4391. The mixture of claim 4386, wherein the condensable hydrocarbons further  
comprise sulfur, and wherein less than about 1 % by weight, when calculated on an  
atomic basis, of the condensable hydrocarbons is sulfur.

4392. The mixture of claim 4386, wherein the condensable hydrocarbons further comprise oxygen containing compounds, wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

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4393. The mixture of claim 4386, wherein the condensable hydrocarbons further comprise multi-ring aromatics, and wherein less than about 5 % by weight of the condensable hydrocarbons comprises multi-ring aromatics with more than two rings.

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4394. The mixture of claim 4386, wherein the condensable hydrocarbons further comprise asphaltenes, and wherein less than about 0.3 % by weight of the condensable hydrocarbons are asphaltenes.

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4395. The mixture of claim 4386, wherein the condensable hydrocarbons comprise cycloalkanes, and wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons are cycloalkanes.

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4396. The mixture of claim 4386, wherein greater than about 10 % by volume and less than about 80 % by volume of the non-condensable hydrocarbons is hydrogen.

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4397. The mixture of claim 4386, further comprising ammonia, and wherein greater than about 0.05 % by weight of the produced mixture is ammonia.

4398. The mixture of claim 4386, further comprising ammonia, and wherein the ammonia is used to produce fertilizer.

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4399. The mixture of claim 4386, wherein about 0.1 % to about 5 % by weight of the condensable hydrocarbons comprises olefins.

4400. The mixture of claim 4386, wherein about 0.1 % to about 2 % by weight of the condensable hydrocarbons comprises olefins.

4401. The mixture of claim 4386, wherein the condensable hydrocarbons comprises oxygenated hydrocarbons, and wherein greater than about 15 % by weight of the condensable hydrocarbons comprises oxygenated hydrocarbons.

4402. The mixture of claim 4386, wherein the mixture comprises hydrocarbons having greater than about 2 carbon atoms, and wherein the weight ratio of hydrocarbons having greater than about 2 carbon atoms to methane is greater than about 0.3.

4403. A condensable mixture produced from a portion of a hydrocarbon containing formation, comprising:

olefins, wherein about 0.1 % by weight to about 15 % by weight of the condensable mixture comprises olefins;

oxygenated hydrocarbons, wherein less than about 15 % by weight of the condensable mixture comprises oxygenated hydrocarbons; and

asphaltenes, wherein less than about 0.1 % by weight of the condensable mixture comprises asphaltenes.

4404. The mixture of claim 4403, wherein the condensable mixture further comprises hydrocarbons having a carbon number of greater than approximately 25, and wherein less than about 15 weight % of the hydrocarbons in the mixture have a carbon number greater than approximately 25.

4405. The mixture of claim 4403, wherein about 0.1 % by weight to about 5 % by weight of the condensable mixture comprises olefins.

4406. The mixture of claim 4403, wherein the condensable mixture further comprises non-condensable hydrocarbons, wherein the non-condensable hydrocarbons comprise ethene and ethane, and wherein a molar ratio of ethene to ethane in the non-condensable hydrocarbons ranges from about 0.001 to about 0.15.

4407. The mixture of claim 4403, wherein the condensable mixture further comprises nitrogen, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable mixture is nitrogen.

5 4408. The mixture of claim 4403, wherein the condensable mixture further comprises oxygen, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable mixture is oxygen.

10 4409. The mixture of claim 4403, wherein the condensable mixture further comprises sulfur, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable mixture is sulfur.

15 4410. The mixture of claim 4403, wherein the condensable mixture further comprises oxygen containing compounds, wherein about 5 % by weight to about 30 % by weight of the condensable mixture comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

20 4411. The mixture of claim 4403, wherein the condensable mixture further comprises aromatic compounds, and wherein greater than about 20 % by weight of the condensable mixture are aromatic compounds.

25 4412. The mixture of claim 4403, wherein the condensable mixture further comprises multi-ring aromatics, and wherein less than about 5 % by weight of the condensable hydrocarbons comprises multi-ring aromatics with more than two rings.

30 4413. The mixture of claim 4403, wherein the condensable mixture further comprises cycloalkanes, and wherein about 5 % by weight to about 30 % by weight of the condensable mixture are cycloalkanes.

4414. The mixture of claim 4403, wherein the condensable mixture comprises non-condensable hydrocarbons, and wherein the non-condensable hydrocarbons comprise



hydrogen, and wherein the hydrogen is greater than about 10 % by volume of the non-condensable hydrocarbons and wherein the hydrogen is less than about 80 % by volume of the non-condensable hydrocarbons.

4415. The mixture of claim 4403, further comprising ammonia, and wherein greater than about 0.05 % by weight of the produced mixture is ammonia.

4416. The mixture of claim 4403, further comprising ammonia, and wherein the ammonia is used to produce fertilizer.

4417. The mixture of claim 4403, wherein about 0.1 % by weight to about 2 % by weight of the condensable mixture comprises olefins.

4418. A condensable mixture produced from a portion of a hydrocarbon containing formation, comprising:

olefins, wherein about 0.1 % by weight to about 2 % by weight of the condensable mixture comprises olefins;

multi-ring aromatics, wherein less than about 2 % by weight of the condensable mixture comprises multi-ring aromatics with more than two rings; and

oxygenated hydrocarbons, wherein greater than about 25 % by weight of the condensable mixture comprises oxygenated hydrocarbons.

4419. The mixture of claim 4418, further comprising hydrocarbons having a carbon number of greater than approximately 25, wherein less than about 5 weight % of the hydrocarbons in the mixture have a carbon number greater than approximately 25.

4420. The mixture of claim 4418, wherein the condensable mixture further comprises nitrogen, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is nitrogen.

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4421. The mixture of claim 4418, wherein the condensable mixture further comprises oxygen, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is oxygen.

5 4422. The mixture of claim 4418, wherein the condensable mixture further comprises sulfur, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is sulfur.

10 4423. The mixture of claim 4418, wherein the condensable mixture further comprises oxygen containing compounds, wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

15 4424. The mixture of claim 4418, wherein the condensable mixture further comprises aromatic compounds, and wherein greater than about 20 % by weight of the condensable mixture are aromatic compounds.

20 4425. The mixture of claim 4418, wherein the condensable mixture further comprises condensable hydrocarbons, and wherein less than about 0.3 % by weight of the condensable hydrocarbons are asphaltenes.

25 4426. The mixture of claim 4418, wherein the condensable mixture further comprises cycloalkanes, and wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons are cycloalkanes.

4427. The mixture of claim 4418, further comprising ammonia, wherein greater than about 0.05 % by weight of the produced mixture is ammonia.

30 4428. The mixture of claim 4418, further comprising ammonia, wherein the ammonia is used to produce fertilizer.

4429. A mixture produced from a portion of a hydrocarbon containing formation, comprising:

non-condensable hydrocarbons and  $H_2$ , wherein greater than about 10% by volume of the non-condensable hydrocarbons and  $H_2$  comprises  $H_2$ ;

ammonia and water, wherein greater than about 0.5 % by weight of the mixture comprises ammonia; and

condensable hydrocarbons.

4430. The mixture of claim 4429, wherein the non-condensable hydrocarbons further comprise hydrocarbons having carbon numbers of less than 5, and wherein a weight ratio of the hydrocarbons having carbon numbers from 2 through 4 to methane, in the mixture is greater than approximately 1.

4431. The mixture of claim 4429, wherein greater than about 0.1 % by weight of the condensable hydrocarbons are olefins, and wherein less than about 15 % by weight of the condensable hydrocarbons are olefins.

4432. The mixture of claim 4429, wherein the non-condensable hydrocarbons further comprise ethene and ethane, wherein a molar ratio of ethene to ethane in the non-condensable hydrocarbons is greater than about 0.001, and wherein a molar ratio of ethene to ethane in the non-condensable hydrocarbons is less than about 0.15.

4433. The mixture of claim 4429, wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is nitrogen.

4434. The mixture of claim 4429, wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is oxygen.

4435. The mixture of claim 4429, wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is sulfur.

4436. The mixture of claim 4429, wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

5 4437. The mixture of claim 4429, wherein greater than about 20 % by weight of the condensable hydrocarbons are aromatic compounds.

4438. The mixture of claim 4429, wherein less than about 5 % by weight of the condensable hydrocarbons comprises multi-ring aromatics with more than two rings.

10 4439. The mixture of claim 4429, wherein less than about 0.3 % by weight of the condensable hydrocarbons are asphaltenes.

15 4440. The mixture of claim 4429, wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons are cycloalkanes.

4441. The mixture of claim 4429, wherein the  $H_2$  is less than about 80 % by volume of the non-condensable hydrocarbons and  $H_2$ .

20 4442. The mixture of claim 4429, wherein the condensable hydrocarbons further comprise sulfur containing compounds.

4443. The mixture of claim 4429, wherein the ammonia is used to produce fertilizer.

25 4444. The mixture of claim 4429, wherein less than about 5% of the condensable hydrocarbons have carbon numbers greater than 25.

30 4445. The mixture of claim 4429, wherein the condensable hydrocarbons comprise olefins, wherein greater than about 0.001 % by weight of the condensable hydrocarbons comprise olefins, and wherein less than about 15% by weight of the condensable hydrocarbons comprise olefins.

5 4446. The mixture of claim 4429, wherein the condensable hydrocarbons comprise olefins, wherein greater than about 0.001 % by weight of the condensable hydrocarbons comprise olefins, and wherein less than about 10% by weight of the condensable hydrocarbons comprise olefins.

10 4447. The mixture of claim 4429, wherein the condensable hydrocarbons comprise oxygenated hydrocarbons, and wherein greater than about 1.5 % by weight of the condensable hydrocarbons comprises oxygenated hydrocarbons.

15 4448. The mixture of claim 4429, wherein the condensable hydrocarbons further comprise nitrogen containing compounds.

20 4449. A method of treating a hydrocarbon containing formation in situ comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, and wherein the unit of heat sources comprises a triangular pattern.

25 4450. The method of claim 4449, wherein three or more of the heat sources are located in the formation in a plurality of the units, and wherein the plurality of units are repeated over an area of the formation to form a repetitive pattern of units.

30 4451. The method of claim 4449, wherein three or more of the heat sources are located in the formation in a plurality of the units, wherein the plurality of units are repeated over an area of the formation to form a repetitive pattern of units, and wherein a ratio of heat sources in the repetitive pattern of units to production wells in the repetitive pattern is less than approximately 5.

4452. The method of claim 4449, wherein three or more of the heat sources are located in the formation in a plurality of the units, wherein the plurality of units are repeated over an area of the formation to form a repetitive pattern of units, wherein three or more

production wells are located within an area defined by the plurality of units, wherein the three or more production wells are located in the formation in a unit of production wells, and wherein the unit of production wells comprises a triangular pattern.

5 4453. The method of claim 4449, wherein three or more of the heat sources are located in the formation in a plurality of the units, wherein the plurality of units are repeated over an area of the formation to form a repetitive pattern of units, wherein three or more injection wells are located within an area defined by the plurality of units, wherein the three or more injection wells are located in the formation in a unit of injection wells, and  
10 wherein the unit of injection wells comprises a triangular pattern.

4454. The method of claim 4449, wherein three or more of the heat sources are located in the formation in a plurality of the units, wherein the plurality of units are repeated over an area of the formation to form a repetitive pattern of units, wherein three or more  
15 production wells and three or more injection wells are located within an area defined by the plurality of units, wherein the three or more production wells are located in the formation in a unit of production wells, wherein the unit of production wells comprises a first triangular pattern, wherein the three or more injection wells are located in the formation in a unit of injection wells, wherein the unit of injection wells comprises a  
20 second triangular pattern, and wherein the first triangular pattern is substantially different than the second triangular pattern.

4455. The method of claim 4449, wherein three or more of the heat sources are located in the formation in a plurality of the units, wherein the plurality of units are repeated over  
25 an area of the formation to form a repetitive pattern of units, wherein three or more monitoring wells are located within an area defined by the plurality of units, wherein the three or more monitoring wells are located in the formation in a unit of monitoring wells, and wherein the unit of monitoring wells comprises a triangular pattern.

30 4456. The method of claim 4449, wherein a production well is located in an area defined by the unit of heat sources.

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4457. The method of claim 4449, wherein three or more of the heat sources are located in the formation in a first unit and a second unit, wherein the first unit is adjacent to the second unit, and wherein the first unit is inverted with respect to the second unit.

4458. The method of claim 4449, wherein a distance between each of the heat sources in the unit of heat sources varies by less than about 20 %.

4459. The method of claim 4449, wherein a distance between each of the heat sources in the unit of heat sources is approximately equal.

4460. The method of claim 4449, wherein providing heat from three or more heat sources comprises substantially uniformly providing heat to at least the portion of the formation.

4461. The method of claim 4449, wherein the heated portion comprises a substantially uniform temperature distribution.

4462. The method of claim 4449, wherein the heated portion comprises a substantially uniform temperature distribution, and wherein a difference between a highest temperature in the heated portion and a lowest temperature in the heated portion comprises less than about 200 °C.

4463. The method of claim 4449, wherein a temperature at an outer lateral boundary of the triangular pattern and a temperature at a center of the triangular pattern are approximately equal.

4464. The method of claim 4449, wherein a temperature at an outer lateral boundary of the triangular pattern and a temperature at a center of the triangular pattern increase substantially linearly after an initial period of time, and wherein the initial period of time comprises less than approximately 3 months.

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4465. The method of claim 4449, wherein a time required to increase an average temperature of the heated portion to a selected temperature with the triangular pattern of heat sources is substantially less than a time required to increase the average temperature of the heated portion to the selected temperature with a hexagonal pattern of heat sources, and wherein a space between each of the heat sources in the triangular pattern is approximately equal to a space between each of the heat sources in the hexagonal pattern.

4466. The method of claim 4449, wherein a time required to increase a temperature at a coldest point within the heated portion to a selected temperature with the triangular pattern of heat sources is substantially less than a time required to increase a temperature at the coldest point within the heated portion to the selected temperature with a hexagonal pattern of heat sources, and wherein a space between each of the heat sources in the triangular pattern is approximately equal to a space between each of the heat sources in the hexagonal pattern.

4467. The method of claim 4449, wherein a time required to increase a temperature at a coldest point within the heated portion to a selected temperature with the triangular pattern of heat sources is substantially less than a time required to increase a temperature at the coldest point within the heated portion to the selected temperature with a hexagonal pattern of heat sources, and wherein a number of heat sources per unit area in the triangular pattern is equal to the number of heat sources per unit are in the hexagonal pattern of heat sources.

4468. The method of claim 4449, wherein a time required to increase a temperature at a coldest point within the heated portion to a selected temperature with the triangular pattern of heat sources is substantially equal to a time required to increase a temperature at the coldest point within the heated portion to the selected temperature with a hexagonal pattern of heat sources, and wherein a space between each of the heat sources in the triangular pattern is approximately 5 m greater than a space between each of the heat sources in the hexagonal pattern.



4469. The method of claim 4449, wherein providing heat from three or more heat sources to at least the portion of formation comprises:

heating a selected volume ( $V$ ) of the hydrocarbon containing formation from three or more of the heat sources, wherein the formation has an average heat capacity ( $C_v$ ), and wherein heat from three or more of the heat sources pyrolyzes at least some hydrocarbons within the selected volume of the formation; and

wherein heating energy/day provided to the volume is equal to or less than  $P_{wr}$ , wherein  $P_{wr}$  is calculated by the equation:

$$P_{wr} = h * V * C_v * \rho_B$$

wherein  $P_{wr}$  is the heating energy/day,  $h$  is an average heating rate of the formation,  $\rho_B$  is formation bulk density, and wherein the heating rate is less than about  $10^\circ\text{C}/\text{day}$ .

4470. The method of claim 4449, wherein three or more of the heat sources comprise electrical heaters.

4471. The method of claim 4449, wherein three or more of the heat sources comprise surface burners.

4472. The method of claim 4449, wherein three or more of the heat sources comprise flameless distributed combustors.

4473. The method of claim 4449, wherein three or more of the heat sources comprise natural distributed combustors.

4474. The method of claim 4449, further comprising:  
allowing the heat to transfer from three or more of the heat sources to a selected section of the formation such that heat from three or more of the heat sources pyrolyzes at least some hydrocarbons within the selected section of the formation; and  
producing a mixture of fluids from the formation.

4475. The method of claim 4474, further comprising controlling a temperature within at least a majority of the selected section of the formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure.

4476. The method of claim 4474, further comprising controlling the heat such that an average heating rate of the selected section is less than about 1.0° C per day during pyrolysis.

4477. The method of claim 4474, wherein allowing the heat to transfer from three or more of the heat sources to the selected section comprises transferring heat substantially by conduction.

4478. The method of claim 4474, wherein providing heat from three or more of the heat sources to at least the portion of the formation comprises heating the selected section such that a thermal conductivity of at least a portion of the selected section is greater than about 0.5 W/m °C.

4479. The method of claim 4474, wherein the produced mixture comprises an API gravity of at least 25°.

4480. The method of claim 4474, wherein the produced mixture comprises condensable hydrocarbons, and wherein about 0.1% by weight to about 15% by weight of the condensable hydrocarbons are olefins.

4481. The method of claim 22, wherein the produced mixture comprises non-condensable hydrocarbons, and wherein a molar ratio of ethene to ethane in the non-condensable hydrocarbons ranges from about 0.001 to about 0.15.

4482. The method of claim 4474, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is nitrogen.

5 4483. The method of claim 4474, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is oxygen.

10 4484. The method of claim 4474, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the condensable hydrocarbons is sulfur.

15 4485. The method of claim 4474, wherein the produced mixture comprises condensable hydrocarbons, wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

20 4486. The method of claim 4474, wherein the produced mixture comprises condensable hydrocarbons, and wherein greater than about 20 % by weight of the condensable hydrocarbons are aromatic compounds.

25 4487. The method of claim 4474, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 5 % by weight of the condensable hydrocarbons comprises multi-ring aromatics with more than two rings.

4488. The method of claim 4474, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 0.1% by weight of the condensable hydrocarbons are asphaltenes.

4489. ~~The method of claim 4474, wherein the produced mixture comprises condensable hydrocarbons, and wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons are cycloalkanes.~~

5 4490. The method of claim 4474, wherein the produced mixture comprises a non-condensable component, wherein the non-condensable component comprises hydrogen, wherein the hydrogen is greater than about 10 % by volume of the non-condensable component, and wherein the hydrogen is less than about 80 % by volume of the non-condensable component.

10 4491. The method of claim 4474, wherein the produced mixture comprises ammonia, and wherein greater than about 0.05 % by weight of the produced mixture is ammonia.

15 4492. The method of claim 4474, wherein the produced mixture comprises ammonia, and wherein the ammonia is used to produce fertilizer.

20 4493. The method of claim 4474, further comprising controlling formation conditions to produce a mixture of hydrocarbon fluids and  $H_2$ , wherein a partial pressure of  $H_2$  within the mixture is greater than about 2.0 bar absolute.

25 4494. The method of claim 4474, further comprising altering a pressure within the formation to inhibit production of hydrocarbons from the formation having carbon numbers greater than about 25.

30 4495. The method of claim 4474, further comprising controlling formation conditions by recirculating a portion of hydrogen from the mixture into the formation.

4496. The method of claim 4474, further comprising:  
providing hydrogen ( $H_2$ ) to the heated section to hydrogenate hydrocarbons  
within the section; and  
~~heating a portion of the section with heat from hydrogenation.~~

4497. The method of claim 4474, further comprising:

producing hydrogen from the formation; and

hydrogenating a portion of the produced condensable hydrocarbons with at least a portion of the produced hydrogen.

4498. The method of claim 4474, wherein allowing the heat to transfer from three or more of the heat sources to the selected section of the formation comprises increasing a permeability of a majority of the selected section to greater than about 100 millidarcy.

4499. The method of claim 4474, wherein allowing the heat to transfer from three or more of the heat sources to the selected section of the formation comprises substantially uniformly increasing a permeability of a majority of the selected section.

4500. The method of claim 4474, further comprising controlling the heat from three of more heat sources to yield greater than about 60 % by weight of condensable hydrocarbons, as measured by the Fischer Assay.

4501. The method of claim 4474, wherein producing the mixture comprises producing the mixture in a production well, and wherein at least about 7 heat sources are disposed in the formation for each production well.

4502. The method of claim 4474, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, and wherein the unit of heat sources comprises a triangular pattern.

4503. The method of claim 4474, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, wherein the unit of heat

sources comprises a triangular pattern, and wherein a plurality of the units are repeated  
~~over an area of the formation to form a repetitive pattern of units.~~

4504. A method for in situ production of synthesis gas from a hydrocarbon containing  
5 formation, comprising:

heating a section of the formation to a temperature sufficient to allow synthesis  
gas generation, wherein a permeability of the section is substantially uniform and greater  
than a permeability of an unheated section of the formation when the temperature  
sufficient to allow synthesis gas generation within the formation is achieved;

10 providing a synthesis gas generating fluid to the section to generate synthesis gas;  
and

removing synthesis gas from the formation.

4505. The method of claim 4504, wherein the permeability of the section is greater than  
15 about 100 millidarcy when the temperature sufficient to allow synthesis gas generation  
within the formation is achieved.

4506. The method of claim 4504, wherein the temperature sufficient to allow synthesis  
gas generation ranges from approximately 400 °C to approximately 1200 °C.

20 4507. The method of claim 4504, further comprising heating the section when providing  
the synthesis gas generating fluid to inhibit temperature decrease in the section due to  
synthesis gas generation.

25 4508. The method of claim 4504, wherein heating the section comprises convecting an  
oxidizing fluid into a portion of the section, wherein the temperature within the section is  
above a temperature sufficient to support oxidation of carbon within the section with the  
oxidizing fluid, and reacting the oxidizing fluid with carbon in the section to generate  
heat within the section.

30 4509. The method of claim 4508, wherein the oxidizing fluid comprises air.

4510. The method of claim 4509, wherein an amount of the oxidizing fluid convected into the section is configured to inhibit formation of oxides of nitrogen by maintaining a reaction temperature below a temperature sufficient to produce oxides of nitrogen compounds.

4511. The method of claim 4504, wherein heating the section comprises diffusing an oxidizing fluid to reaction zones adjacent to wellbores within the formation, oxidizing carbon within the reaction zone to generate heat, and transferring the heat to the section.

4512. The method of claim 4504, wherein heating the section comprises heating the section by transfer of heat from one or more of electrical heaters.

4513. The method of claim 4504, wherein heating the section to a temperature sufficient to allow synthesis gas generation and providing a synthesis gas generating fluid to the section comprises introducing steam into the section to heat the formation and to generate synthesis gas.

4514. The method of claim 4504, further comprising controlling the heating of the section and provision of the synthesis gas generating fluid to maintain a temperature within the section above the temperature sufficient to generate synthesis gas.

4515. The method of claim 4504, further comprising:  
monitoring a composition of the produced synthesis gas; and  
controlling heating of the section and provision of the synthesis gas generating fluid to maintain the composition of the produced synthesis gas within a selected range.

4516. The method of claim 4515, wherein the selected range comprises a ratio of H<sub>2</sub> to CO of about 2:1.

4517. The method of claim 4504, wherein the synthesis gas generating fluid comprises liquid water.

4518. The method of claim 4504, wherein the synthesis gas generating fluid comprises steam.

4519. The method of claim 4504, wherein the synthesis gas generating fluid comprises water and carbon dioxide, and wherein the carbon dioxide inhibits production of carbon dioxide from carbon containing material within the section.

4520. The method of claim 4519, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

4521. The method of claim 4504, wherein the synthesis gas generating fluid comprises carbon dioxide, and wherein a portion of the carbon dioxide reacts with carbon in the formation to generate carbon monoxide.

4522. The method of claim 4521, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

4523. The method of claim 4504, wherein providing the synthesis gas generating fluid to the section comprises raising a water table of the formation to allow water to flow into the section.

4524. The method of claim 4504, wherein the synthesis gas is removed from a producer well equipped with a heating source, and wherein a portion of the heating source adjacent to a synthesis gas producing zone operates at a substantially constant temperature to promote production of the synthesis gas wherein the synthesis gas has a selected composition.



4525. The method of claim 4524, wherein the substantially constant temperature is about 700 °C, and wherein the selected composition has a H<sub>2</sub> to CO ratio of about 2:1.

4526. The method of claim 4504, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers less than 5, and wherein at least a portion of the hydrocarbons are subjected to a reaction within the section to increase a H<sub>2</sub> concentration of the generated synthesis gas.

4527. The method of claim 4504, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers greater than 4, and wherein at least a portion of the hydrocarbons react within the section to increase an energy content of the synthesis gas removed from the formation.

4528. The method of claim 4504, further comprising maintaining a pressure within the formation during synthesis gas generation, and passing produced synthesis gas through a turbine to generate electricity.

4529. The method of claim 4504, further comprising generating electricity from the synthesis gas using a fuel cell.

4530. The method of claim 4504, further comprising generating electricity from the synthesis gas using a fuel cell, separating carbon dioxide from a fluid exiting the fuel cell, and storing a portion of the separated carbon dioxide within a spent section of the formation.

4531. The method of claim 4504, further comprising using a portion of the synthesis gas as a combustion fuel to heat the formation.

4532. The method of claim 4504, further comprising converting at least a portion of the produced synthesis gas to condensable hydrocarbons using a Fischer-Tropsch synthesis process.

4533. The method of claim 4504, ~~further comprising converting~~ at least a portion of the produced synthesis gas to methanol.

5 4534. The method of claim 4504, further comprising converting at least a portion of the produced synthesis gas to gasoline.

10 4535. The method of claim 4504, further comprising converting at least a portion of the synthesis gas to methane using a catalytic methanation process.

15 4536. The method of claim 4504, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, and wherein the unit of heat sources comprises a triangular pattern.

20 4537. The method of claim 4504, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, wherein the unit of heat sources comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

25 4538. A method of treating a hydrocarbon containing formation in situ, comprising:  
providing heat from one or more heat sources to at least a portion of the formation;  
allowing the heat to transfer from the one or more heat sources to substantially uniformly increase a permeability of the portion and to increase a temperature of the portion to a temperature sufficient to allow synthesis gas generation;  
providing a synthesis gas generating fluid to at least the portion of the selected section, wherein the synthesis gas generating fluid comprises carbon dioxide;  
30 obtaining a portion of the carbon dioxide of the synthesis gas generating fluid from the formation; and

producing synthesis gas from the formation.

4539. The method of claim 4538, wherein the temperature sufficient to allow synthesis gas generation is within a range from about 400 °C to about 1200 °C.

4540. The method of claim 4538, further comprising using a second portion of the separated carbon dioxide as a flooding agent to produce hydrocarbon bed methane from a hydrocarbon containing formation.

4541. The method of claim 4540, wherein the hydrocarbon containing formation is a deep hydrocarbon containing formation over 760 m below ground surface.

4542. The method of claim 4540, wherein the hydrocarbon containing formation adsorbs some of the carbon dioxide to sequester the carbon dioxide.

4543. The method of claim 4538, further comprising using a second portion of the separated carbon dioxide as a flooding agent for enhanced oil recovery.

4544. The method of claim 4538, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers less than 5, and wherein at least a portion of the hydrocarbons undergo a reaction within the selected section to increase a H<sub>2</sub> concentration within the produced synthesis gas.

4545. The method of claim 4538, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers greater than 4, and wherein at least a portion of the hydrocarbons react within the selected section to increase an energy content of the produced synthesis gas.

4546. The method of claim 4538, further comprising maintaining a pressure within the formation during synthesis gas generation, and passing produced synthesis gas through a turbine to generate electricity.

4547. The method of claim 4538, further comprising generating electricity from the synthesis gas using a fuel cell.

5 4548. The method of claim 4538, further comprising generating electricity from the synthesis gas using a fuel cell, separating carbon dioxide from a fluid exiting the fuel cell, and storing a portion of the separated carbon dioxide within a spent portion of the formation.

10 4549. The method of claim 4538, further comprising using a portion of the synthesis gas as a combustion fuel for heating the formation.

15 4550. The method of claim 4538, further comprising converting at least a portion of the produced synthesis gas to condensable hydrocarbons using a Fischer-Tropsch synthesis process.

4551. The method of claim 4538, further comprising converting at least a portion of the produced synthesis gas to methanol.

20 4552. The method of claim 4538, further comprising converting at least a portion of the produced synthesis gas to gasoline.

4553. The method of claim 4538, further comprising converting at least a portion of the synthesis gas to methane using a catalytic methanation process.

25 4554. The method of claim 4538, wherein a temperature of the one or more heat sources wellbore is maintained at a temperature of less than approximately 700 °C to produce a synthesis gas having a ratio of H<sub>2</sub> to carbon monoxide of greater than about 2.

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4555. The method of claim 4538, wherein a temperature of the one or more heat sources wellbore is maintained at a temperature of greater than approximately 700 °C to produce a synthesis gas having a ratio of H<sub>2</sub> to carbon monoxide of less than about 2.

5 4556. The method of claim 4538, wherein a temperature of the one or more heat sources wellbore is maintained at a temperature of approximately 700 °C to produce a synthesis gas having a ratio of H<sub>2</sub> to carbon monoxide of approximately 2.

10 4557. The method of claim 4538, wherein a heat source of the one or more of heat sources comprises an electrical heater.

4558. The method of claim 4538, wherein a heat source of the one or more heat sources comprises a natural distributor heater.

15 4559. The method of claim 4538, wherein a heat source of the one or more heat sources comprises a flameless distributor combustor (FDC) heater, and wherein fluids are produced from the wellbore of the FDC heater through a conduit positioned within the wellbore.

20 4560. The method of claim 4538, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, and wherein the unit of heat sources comprises a triangular pattern.

25 4561. The method of claim 4538, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, wherein the unit of heat sources comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

30 4562. A method of in situ synthesis gas production, comprising:

providing heat from one or more flameless distributed combustor heaters to at least a first portion of a carbon containing formation;

allowing the heat to transfer from the one or more heaters to a selected section of the formation such that the heat from the one or more heaters substantially uniformly increases a permeability of the selected section, and to raise a temperature of the selected section to a temperature sufficient to generate synthesis gas;

introducing a synthesis gas producing fluid into the selected section to generate synthesis gas; and

removing synthesis gas from the formation.

4563. The method of claim 4562, wherein the one or more heaters comprise at least two heaters, and wherein superposition of heat from at least the two heaters substantially uniformly increases a permeability of the selected section, and raises a temperature of the selected section to a temperature sufficient to generate synthesis gas.

4564. The method of claim 4562, further comprising producing the synthesis gas from the formation under pressure, and generating electricity from the produced synthesis gas by passing the produced synthesis gas through a turbine.

4565. The method of claim 4562, further comprising producing pyrolyzation products from the formation when raising the temperature of the selected section to the temperature sufficient to generate synthesis gas.

4566. The method of claim 4562, further comprising separating a portion of carbon dioxide from the removed synthesis gas, and storing the carbon dioxide within a spent portion of the formation.

4567. The method of claim 4562, further comprising storing carbon dioxide within a spent portion of the formation, wherein an amount of carbon dioxide stored within the spent portion of the formation is equal to or greater than an amount of carbon dioxide within the removed synthesis gas.

4568. The method of claim 4562, further comprising separating a portion of H<sub>2</sub> from the removed synthesis gas; and using a portion of the separated H<sub>2</sub> as fuel for the one or more heaters.

4569. The method of claim 4568, further comprising using a portion of exhaust products from one or more heaters as a portion of the synthesis gas producing fluid

4570. The method of claim 4562, further comprising using a portion of the removed synthesis gas with a fuel cell to generate electricity.

4571. The method of claim 4570, wherein the fuel cell produces steam, and wherein a portion of the steam is used as a portion of the synthesis gas producing fluid.

4572. The method of claim 4570, wherein the fuel cell produces carbon dioxide, and wherein a portion of the carbon dioxide is introduced into the formation to react with carbon within the formation to produce carbon monoxide.

4573. The method of claim 4570, wherein the fuel cell produces carbon dioxide, and storing an amount of carbon dioxide within a spent portion of the formation equal or greater to an amount of the carbon dioxide produced by the fuel cell.

4574. The method of claim 4562, further comprising using a portion of the removed synthesis gas as a feed product for formation of hydrocarbons.

4575. The method of claim 4562, wherein the synthesis gas producing fluid comprises hydrocarbons having carbon numbers less than 5, and wherein the hydrocarbons crack within the formation to increase an amount of H<sub>2</sub> within the generated synthesis gas.

4576. The method of claim 4562, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat

sources are located in the formation in a unit of heat sources, and wherein the unit of heat sources comprises a triangular pattern.

4577. The method of claim 4562, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, wherein the unit of heat sources comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

4578. A method of treating a hydrocarbon containing formation, comprising:  
heating a portion of the formation with one or more electrical heaters to a temperature sufficient to pyrolyze hydrocarbons within the portion;  
producing pyrolyzation fluid from the formation;  
separating a fuel cell feed stream from the pyrolyzation fluid; and  
directing the fuel cell feed stream to a fuel cell to produce electricity;

4579. The method of claim 4578, wherein the fuel cell is a molten carbonate fuel cell.

4580. The method of claim 4578, wherein the fuel cell is a solid oxide fuel cell.

4581. The method of claim 4578, further comprising using a portion of the produced electricity to power the electrical heaters.

4582. The method of claim 4578, wherein heating the portion of the formation is performed at a rate sufficient to increase a permeability of the portion and to produce a substantially uniform permeability within the portion.

4583. The method of claim 4578, wherein the fuel cell feed stream comprises  $H_2$  and hydrocarbons having a carbon number of less than 5.

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4584. The method of claim 4578, wherein the fuel cell feed stream comprises H<sub>2</sub> and hydrocarbons having a carbon number of less than 3.

4585. The method of claim 4578, further comprising hydrogenating the pyrolyzation fluid with a portion of H<sub>2</sub> from the pyrolyzation fluid.

4586. The method of claim 4578, wherein the hydrogenation is done in situ by directing the H<sub>2</sub> into the formation.

4587. The method of claim 4578, wherein the hydrogenation is done in a surface unit.

4588. The method of claim 4578, further comprising directing hydrocarbon fluid having carbon numbers less than 5 adjacent to at least one of the electrical heaters, cracking a portion of the hydrocarbons to produce H<sub>2</sub>, and producing a portion of the hydrogen from the formation.

4589. The method of claim 4588, further comprising directing an oxidizing fluid adjacent to at least the one of the electrical heaters, oxidizing coke deposited on or near the at least one of the electrical heaters with the oxidizing fluid.

4590. The method of claim 4578, further comprising storing CO<sub>2</sub> from the fuel cell within the formation.

4591. The method of claim 4590, wherein the CO<sub>2</sub> is adsorbed to carbon material within a spent portion of the formation.

4592. The method of claim 4578, further comprising cooling the portion to form a spent portion of formation.

4593. The method of claim 4592, wherein cooling the portion comprises introducing water into the portion to produce steam, and removing steam from the formation.

4594. The method of claim 4593, further comprising using a portion of the removed steam to heat a second portion of the formation.

5 4595. The method of claim 4593, further comprising using a portion of the removed steam as a synthesis gas producing fluid in a second portion of the formation.

4596. The method of claim 4578, further comprising:

10 heating the portion to a temperature sufficient to support generation of synthesis gas after production of the pyrolyzation fluids;

introducing a synthesis gas producing fluid into the portion to generate synthesis gas; and

removing a portion of the synthesis gas from the formation.

15 4597. The method of claim 4596, further comprising producing the synthesis gas from the formation under pressure, and generating electricity from the produced synthesis gas by passing the produced synthesis gas through a turbine.

20 4598. The method of claim 4596, further comprising using a first portion of the removed synthesis gas as fuel cell feed.

4599. The method of claim 4596, further comprising producing steam from operation of the fuel cell, and using the steam as part of the synthesis gas producing fluid.

25 4600. The method of claim 4596, further comprising using carbon dioxide from the fuel cell as a part of the synthesis gas producing fluid.

4601. The method of claim 4596, further comprising using a portion of the synthesis gas to produce hydrocarbon product.

30

4602. The method of claim 4596, further comprising cooling the portion to form a spent portion of formation.

4603. The method of claim 4602, wherein cooling the portion comprises introducing water into the portion to produce steam, and removing steam from the formation.

4604. The method of claim 4603, further comprising using a portion of the removed steam to heat a second portion of the formation.

4605. The method of claim 4603, further comprising using a portion of the removed steam as a synthesis gas producing fluid in a second portion of the formation.

4606. The method of claim 4578, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, and wherein the unit of heat sources comprises a triangular pattern.

4607. The method of claim 4578, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, wherein the unit of heat sources comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

4608. A method for in situ production of synthesis gas from a hydrocarbon containing formation, comprising:

providing heat from one or more heat sources to at least a portion of the formation;

allowing the heat to transfer from the one or more heat sources to a selected section of the formation such that the heat from the one or more heat sources pyrolyzes at least some of the hydrocarbons within the selected section of the formation;

producing pyrolysis products from the formation;

heating at least a portion of the selected section to a temperature sufficient to generate synthesis gas;

providing a synthesis gas generating fluid to at least the portion of the selected section to generate synthesis gas; and

5 producing a portion of the synthesis gas from the formation.

4609. The method of claim 4608, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from at least the two heat sources pyrolyzes at least some hydrocarbons within the selected section of the formation.

4610. The method of claim 4608, further comprising allowing the heat to transfer from the one or more heat sources to the selected section to substantially uniformly increase a permeability of the selected section.

4611. The method of claim 4608, further comprising controlling heat transfer from the one or more heat sources to produce a permeability within the selected section of greater than about 100 millidarcy.

4612. The method of claim 4608, further comprising heating at least the portion of the selected section when providing the synthesis gas generating fluid to inhibit temperature decrease within the selected section during synthesis gas generation.

4613. The method of claim 4608, wherein the temperature sufficient to allow synthesis gas generation is within a range from approximately 400 °C to approximately 1200 °C.

4614. The method of claim 4608, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation comprises:

heating zones adjacent to wellbores of one or more heat sources with heaters disposed in the wellbores, wherein the heaters are configured to raise temperatures of the

zones to temperatures sufficient to support reaction of carbon-containing material within the zones with an oxidizing fluid;

introducing the oxidizing fluid to the zones substantially by diffusion;

allowing the oxidizing fluid to react with at least a portion of the carbon-containing material within the zones to produce heat in the zones; and

transferring heat from the zones to the selected section.

4615. The method of claim 4608, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation comprises:

introducing an oxidizing fluid into the formation through a wellbore;

transporting the oxidizing fluid substantially by convection into the portion of the selected section, wherein the portion of the selected section is at a temperature sufficient to support an oxidation reaction with the oxidizing fluid; and

reacting the oxidizing fluid within the portion of the selected section to generate heat and raise the temperature of the portion.

4616. The method of claim 4608, wherein the one or more heat sources comprise one or more electrical heaters disposed in the formation.

4617. The method of claim 4608, wherein one or more heat sources comprise one or more heater wells, wherein at least one heater well comprises a conduit disposed within the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

4618. The method of claim 4608, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation and providing a synthesis gas generating fluid to at least the portion of the selected section comprises introducing steam into the portion.

4619. The method of claim 4608, further comprising controlling the heating of at least the portion of selected section and provision of the synthesis gas generating fluid to

maintain a temperature within at least the portion of the selected section above the temperature sufficient to generate synthesis gas.

4620. The method of claim 4608, further comprising:

monitoring a composition of the produced synthesis gas; and  
controlling heating of at least the portion of selected section and provision of the synthesis gas generating fluid to maintain the composition of the produced synthesis gas within a desired range.

4621. The method of claim 4608, wherein the synthesis gas generating fluid comprises liquid water.

4622. The method of claim 4608, wherein the synthesis gas generating fluid comprises steam.

4623. The method of claim 4608, wherein the synthesis gas generating fluid comprises water and carbon dioxide, wherein the carbon dioxide inhibits production of carbon dioxide from the selected section.

4624. The method of claim 4623, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

4625. The method of claim 4608, wherein the synthesis gas generating fluid comprises carbon dioxide, and wherein a portion of the carbon dioxide reacts with carbon in the formation to generate carbon monoxide.

4626. The method of claim 4625, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

4627. The method of claim 4608, wherein providing the synthesis gas generating fluid to at least the portion of the selected section comprises raising a water table of the formation to allow water to flow into the at least the portion of the selected section.

5 4628. The method of claim 4608, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers less than 5, and wherein at least a portion of the hydrocarbons are subjected to a reaction within at least the portion of the selected section to increase a H<sub>2</sub> concentration within the produced synthesis gas.

10 4629. The method of claim 4608, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers greater than 4, and wherein at least a portion of the hydrocarbons react within at least the portion of the selected section to increase an energy content of the produced synthesis gas.

15 4630. The method of claim 4608, further comprising maintaining a pressure within the formation during synthesis gas generation, and passing produced synthesis gas through a turbine to generate electricity.

20 4631. The method of claim 4608, further comprising generating electricity from the synthesis gas using a fuel cell.

25 4632. The method of claim 4608, further comprising generating electricity from the synthesis gas using a fuel cell, separating carbon dioxide from a fluid exiting the fuel cell, and storing a portion of the separated carbon dioxide within a spent section of the formation.

4633. The method of claim 4608, further comprising using a portion of the synthesis gas as a combustion fuel for the one or more heat sources.

4634. The method of claim 4608, further comprising converting at least a portion of the produced synthesis gas to condensable hydrocarbons using a Fischer-Tropsch synthesis process.

5 4635. The method of claim 4608, further comprising converting at least a portion of the produced synthesis gas to methanol.

4636. The method of claim 4608, further comprising converting at least a portion of the produced synthesis gas to gasoline.

10 4637. The method of claim 4608, further comprising converting at least a portion of the synthesis gas to methane using a catalytic methanation process.

15 4638. The method of claim 4608, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, and wherein the unit of heat sources comprises a triangular pattern.

20 4639. The method of claim 4608, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, wherein the unit of heat sources comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

25 4640. A method for in situ production of synthesis gas from a hydrocarbon containing formation, comprising:  
     heating a first portion of the formation to pyrolyze some hydrocarbons within the first portion;  
     allowing the heat to transfer from one or more heat sources to a selected section  
 30 of the formation,  
     pyrolyzing hydrocarbons within the selected section;



producing fluid from the first portion, wherein the fluid comprises an aqueous fluid and a hydrocarbon fluid;

heating a second portion of the formation to a temperature sufficient to allow synthesis gas generation;

5 introducing at least a portion of the aqueous fluid to the second section after the section reaches the temperature sufficient to allow synthesis gas generation; and producing synthesis gas from the formation.

10 4641. The method of claim 4640, wherein the temperature sufficient to allow synthesis gas generation ranges from approximately 400 °C to approximately 1200 °C.

15 4642. The method of claim 4640, further comprising separating ammonia within the aqueous phase from the aqueous phase prior to introduction of at least the portion of the aqueous fluid to the second section.

20 4643. The method of claim 4640, wherein a permeability of the second portion of the formation is substantially uniform and greater than about 100 millidarcy when the temperature sufficient to allow synthesis gas generation is achieved.

25 4644. The method of claim 4640, further comprising heating the second portion of the formation during introduction of at least the portion of the aqueous fluid to the second section to inhibit temperature decrease in the second section due to synthesis gas generation.

30 4645. The method of claim 4640, wherein heating the second portion of the formation comprises convecting an oxidizing fluid into a portion of the second portion that is above a temperature sufficient to support oxidation of carbon within the portion with the oxidizing fluid, and reacting the oxidizing fluid with carbon in the portion to generate heat within the portion.

4646. The method of claim 4640, wherein heating the second portion of the formation comprises diffusing an oxidizing fluid to reaction zones adjacent to wellbores within the formation, oxidizing carbon within the reaction zones to generate heat, and transferring the heat to the second portion.

5

4647. The method of claim 4640, wherein heating the second portion of the formation comprises heating the second section by transfer of heat from one or more electrical heaters.

10

4648. The method of claim 4640, wherein heating the second portion of the formation comprises heating the second section with a flameless distributor combustor.

4649. The method of claim 4640, wherein heating the second portion of the formation comprises injecting steam into at least the portion of the formation.

15

4650. The method of claim 4640, wherein at least a portion of the aqueous fluid comprises a liquid phase.

20

4651. The method of claim 4640, wherein the aqueous fluid comprises a vapor phase.

4652. The method of claim 4640, further comprising adding carbon dioxide to at least the portion of aqueous fluid to inhibit production of carbon dioxide from carbon within the formation.

25

4653. The method of claim 4652, wherein a portion of the carbon dioxide comprises carbon dioxide removed from the formation.

30

4654. The method of claim 4640, further comprising adding hydrocarbons with carbon numbers less than 5 to at least the portion of the aqueous fluid to increase a H<sub>2</sub> concentration within the produced synthesis gas.

4655. The method of claim 4640, further comprising adding hydrocarbons with carbon numbers less than 5 to at least the portion of the aqueous fluid to increase a  $H_2$  concentration within the produced synthesis gas, wherein the hydrocarbons are obtained from the produced fluid.

4656. The method of claim 4640, further comprising adding hydrocarbons greater than 4 to at least the portion of the aqueous fluid to increase energy content of the produced synthesis gas.

4657. The method of claim 4640, further comprising adding hydrocarbons greater than 4 to at least the portion of the aqueous fluid to increase energy content of the produced synthesis gas, wherein the hydrocarbons are obtained from the produced fluid.

4658. The method of claim 4640, further comprising maintaining a pressure within the formation during synthesis gas generation, and passing produced synthesis gas through a turbine to generate electricity.

4659. The method of claim 4640, further comprising generating electricity from the synthesis gas using a fuel cell.

4660. The method of claim 4640, further comprising generating electricity from the synthesis gas using a fuel cell, separating carbon dioxide from a fluid exiting the fuel cell, and storing a portion of the separated carbon dioxide within a spent portion of the formation.

4661. The method of claim 4640, further comprising using a portion of the synthesis gas as a combustion fuel for the one or more heat sources.

4662. The method of claim 4640, further comprising converting at least a portion of the produced synthesis gas to condensable hydrocarbons using a Fischer-Tropsch synthesis process.

4663. The method of claim 4640, further comprising converting at least a portion of the produced synthesis gas to methanol.

5 4664. The method of claim 4640, further comprising converting at least a portion of the produced synthesis gas to gasoline.

4665. The method of claim 4640, further comprising converting at least a portion of the synthesis gas to methane using a catalytic methanation process.

10 4666. The method of claim 4640, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, and wherein the unit of heat sources comprises a triangular pattern.

15 4667. The method of claim 4640, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, wherein the unit of heat sources comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

20 4668. A method for in situ production of synthesis gas from a carbon containing formation, comprising:

25 heating a portion of the formation with one or more heat sources to create increased and substantially uniform permeability within a portion of the formation and to raise a temperature within the portion to a temperature sufficient to allow synthesis gas generation;

30 providing a synthesis gas generating fluid into the portion through at least one injection wellbore to generate synthesis gas from hydrocarbons and the synthesis gas generating fluid; and

producing synthesis gas from at least one heat source wellbore in which is positioned proximate to a heat source of the one or more heat sources.

4669. The method of claim 4668, wherein the temperature sufficient to allow synthesis gas generation is within a range from about 400° C to about 1200 °C.

4670. The method of claim 4668, wherein creating a substantially uniform permeability comprises heating the portion to a temperature within a range sufficient to pyrolyze hydrocarbons within the portion, raising the temperature within the portion at a rate of less than about 5 °C per day during pyrolyzation and removing a portion of pyrolyzed fluid from the formation.

4671. The method of claim 4668, further comprising removing fluid from the formation through at least the one injection wellbore prior to heating the selected section to the temperature sufficient to allow synthesis gas generation.

4672. The method of claim 4668, wherein the injection wellbore comprises a wellbore of a heat source in which is positioned a heat source of the one or more heat sources.

4673. The method of claim 4668, further comprising heating the selected portion during providing the synthesis gas generating fluid to inhibit temperature decrease in at least the portion of the selected section due to synthesis gas generation.

4674. The method of claim 4668, further comprising providing a portion of the heat needed to raise the temperature sufficient to allow synthesis gas generation by convecting an oxidizing fluid to hydrocarbons within the selected section to oxidize a portion of the hydrocarbons and generate heat.

4675. The method of claim 4668, further comprising controlling the heating of the selected section and provision of the synthesis gas generating fluid to maintain a



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4684. The method of claim 4668, wherein providing the synthesis gas generating fluid to the selected section comprises raising a water table of the formation to allow water to enter the selected section.

4685. The method of claim 4668, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers less than 5, and wherein at least a portion of the hydrocarbons undergo a reaction within the selected section to increase a  $H_2$  concentration within the produced synthesis gas.

4686. The method of claim 4668, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers greater than 4, and wherein at least a portion of the hydrocarbons react within the selected section to increase an energy content of the produced synthesis gas.

4687. The method of claim 4668, further comprising maintaining a pressure within the formation during synthesis gas generation, and passing produced synthesis gas through a turbine to generate electricity.

4688. The method of claim 4668, further comprising generating electricity from the synthesis gas using a fuel cell.

4689. The method of claim 4668, further comprising generating electricity from the synthesis gas using a fuel cell, separating carbon dioxide from a fluid exiting the fuel cell, and storing a portion of the separated carbon dioxide within a spent portion of the formation.

4690. The method of claim 4668, further comprising using a portion of the synthesis gas as a combustion fuel for heating the formation.

4691. The method of claim 4668, further comprising converting at least a portion of the produced synthesis gas to condensable hydrocarbons using a Fischer-Tropsch synthesis process.

4692. The method of claim 4668, further comprising converting at least a portion of the produced synthesis gas to methanol.

4693. The method of claim 4668, further comprising converting at least a portion of the produced synthesis gas to gasoline.

4694. The method of claim 4668, further comprising converting at least a portion of the synthesis gas to methane using a catalytic methanation process.

4695. The method of claim 4668, wherein a temperature of at least the one heat source wellbore is maintained at a temperature of less than approximately 700 °C to produce a synthesis gas having a ratio of H<sub>2</sub> to carbon monoxide of greater than about 2.

4696. The method of claim 4668, wherein a temperature of at least the one heat source wellbore is maintained at a temperature of greater than approximately 700 °C to produce a synthesis gas having a ratio of H<sub>2</sub> to carbon monoxide of less than about 2.

4697. The method of claim 4668, wherein a temperature of at least the one heat source wellbore is maintained at a temperature of approximately 700 °C to produce a synthesis gas having a ratio of H<sub>2</sub> to carbon monoxide of approximately 2.

4698. The method of claim 4668, wherein a heat source of the one or more heat sources comprises an electrical heater.

4699. The method of claim 4668, wherein a heat source of the one or more heat sources comprises a natural distributor heater.



4700. The method of claim 4668, wherein a heat source of the one or more heat sources comprises a flameless distributor combustor (FDC) heater, and wherein fluids are produced from the wellbore of the FDC heater through a conduit positioned within the wellbore.

4701. The method of claim 4668, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, and wherein the unit of heat sources comprises a triangular pattern.

4702. The method of claim 4668, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, wherein the unit of heat sources comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

4703. A method of treating a hydrocarbon containing formation in situ, comprising:  
providing heat from one or more heat sources to at least a portion of the formation;  
allowing the heat to transfer from the one or more heat sources to a selected section of the formation such that the heat from the one or more heat sources pyrolyzes at least a portion of the carbon containing material within the selected section of the formation;  
producing pyrolysis products from the formation;  
heating a first portion of a formation with one or more heat sources to a temperature sufficient to allow generation of synthesis gas;  
providing a first synthesis gas generating fluid to the first portion to generate a first synthesis gas;  
removing a portion of the first synthesis gas from the formation;

heating a second portion of a formation with one more heat sources to a temperature sufficient to allow generation of synthesis gas having a H<sub>2</sub> to CO ratio greater than a H<sub>2</sub> to CO ratio of the first synthesis gas;

providing a second synthesis gas generating component to the second portion to generate a second synthesis gas;

removing a portion of the second synthesis gas from the formation; and

blending a portion of the first synthesis gas with a portion of the second synthesis gas to produce a blended synthesis gas having a selected H<sub>2</sub> to CO ratio.

4704. The method of claim 4703, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from at least the two heat sources pyrolyzes at least some hydrocarbons within the selected section of the formation.

4705. The method of claim 4703, wherein the first synthesis gas generating fluid and second synthesis gas generating fluid are the same component.

4706. The method of claim 4703, further comprising controlling the temperature in the first portion to control a composition of the first synthesis gas.

4707. The method of claim 4703, further comprising controlling the temperature in the second portion to control a composition of the second synthesis gas.

4708. The method of claim 4703, wherein the selected ratio is controlled to be approximately 2:1 H<sub>2</sub> to CO.

4709. The method of claim 4703, wherein the selected ratio is controlled to range from approximately 1.8:1 to approximately 2.2:1 H<sub>2</sub> to CO.

4710. The method of claim 4703, wherein the selected ratio is controlled to be approximately 3:1 H<sub>2</sub> to CO.

4711. The method of claim 4703, wherein the selected ratio is controlled to range from approximately 2.8:1 to approximately 3.2:1 H<sub>2</sub> to CO.

4712. The method of claim 4703, further comprising providing at least a portion of the produced blended synthesis gas to a condensable hydrocarbon synthesis process to produce condensable hydrocarbons.

4713. The method of claim 4712, wherein the condensable hydrocarbon synthesis process comprises a Fischer-Tropsch process.

4714. The method of claim 4713, further comprising cracking at least a portion of the condensable hydrocarbons to form middle distillates.

4715. The method of claim 4703, further comprising providing at least a portion of the produced blended synthesis gas to a catalytic methanation process to produce methane.

4716. The method of claim 4703, further comprising providing at least a portion of the produced blended synthesis gas to a methanol-synthesis process to produce methanol.

4717. The method of claim 4703, further comprising providing at least a portion of the produced blended synthesis gas to a gasoline-synthesis process to produce gasoline.

4718. The method of claim 4703, wherein removing a portion of the second synthesis gas comprises withdrawing second synthesis gas through a production well, wherein a temperature of the production well adjacent to a second synthesis gas production zone is maintained at a substantially constant temperature configured to produce second synthesis gas having the H<sub>2</sub> to CO ratio greater than the first synthesis gas.

4719. The method of claim 4703, wherein the first synthesis gas producing fluid comprises CO<sub>2</sub> and wherein the temperature of the first portion is at a temperature that

will result in conversion of CO<sub>2</sub> and carbon from the first portion to CO to generate a CO rich first synthesis gas.

4720. The method of claim 4703, wherein the second synthesis gas producing fluid comprises water and hydrocarbons having carbon numbers less than 5, and wherein at least a portion of the hydrocarbons react within the formation to increase a H<sub>2</sub> concentration within the produced second synthesis gas.

4721. The method of claim 4703, wherein blending a portion of the first synthesis gas with a portion of the second synthesis gas comprises producing an intermediate mixture having a H<sub>2</sub> to CO mixture of less than the selected ratio, and subjecting the intermediate mixture to a shift reaction to reduce an amount of CO and increase an amount of H<sub>2</sub> to produce the selected ratio of H<sub>2</sub> to CO.

4722. The method of claim 4703, further comprising removing an excess of first synthesis gas from the first portion to have an excess of CO, subjecting the first synthesis gas to a shift reaction to reduce an amount of CO and increase an amount of H<sub>2</sub> before blending the first synthesis gas with the second synthesis gas.

4723. The method of claim 4703, further comprising removing the first synthesis gas from the formation under pressure, and passing removed first synthesis gas through a turbine to generate electricity.

4724. The method of claim 4703, further comprising removing the second synthesis gas from the formation under pressure, and passing removed second synthesis gas through a turbine to generate electricity.

4725. The method of claim 4703, further comprising generating electricity from the blended synthesis gas using a fuel cell.



allowing the oxidizing fluid to react with at least a portion of the carbon-containing material within the zones to produce heat in the zones; and transferring heat from the zones to the selected section.

5 4733. The method of claim 4703, wherein heating the second portion of the selected section to a temperature sufficient to allow synthesis gas generation comprises:

heating zones adjacent to wellbores of one or more heat sources with heaters disposed in the wellbores, wherein the heaters are configured to raise temperatures of the zones to temperatures sufficient to support reaction of carbon-containing material within the zones with an oxidizing fluid;

10 introducing the oxidizing fluid to the zones substantially by diffusion;

allowing the oxidizing fluid to react with at least a portion of the carbon-containing material within the zones to produce heat in the zones; and transferring heat from the zones to the selected section.

15 4734. The method of claim 4703, wherein heating the first portion of the selected section to a temperature sufficient to allow synthesis gas generation comprises:

introducing an oxidizing fluid into the formation through a wellbore;

20 transporting the oxidizing fluid substantially by convection into the first portion of the selected section, wherein the first portion of the selected section is at a temperature sufficient to support an oxidization reaction with the oxidizing fluid; and

reacting the oxidizing fluid within the first portion of the selected section to generate heat and raise the temperature of the first portion.

25 4735. The method of claim 4703, wherein heating the second portion of the selected section to a temperature sufficient to allow synthesis gas generation comprises:

introducing an oxidizing fluid into the formation through a wellbore;

30 transporting the oxidizing fluid substantially by convection into the second portion of the selected section, wherein the second portion of the selected section is at a temperature sufficient to support an oxidization reaction with the oxidizing fluid; and

reacting the oxidizing fluid within the second portion of the selected section to generate heat and raise the temperature of the second portion.

5 4736. The method of claim 4703, wherein the one or more heat sources comprise one or more electrical heaters disposed in the formation.

4737. The method of claim 4703, wherein the one or more heat sources comprises one or more natural distributor combustors.

10 4738. The method of claim 4703, wherein the one or more heat sources comprise one or more heater wells, wherein at least one heater well comprises a conduit disposed within the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

15 4739. The method of claim 4703, wherein heating the first portion of the selected section to a temperature sufficient to allow synthesis gas generation and providing a first synthesis gas generating fluid to the first portion of the selected section comprises introducing steam into the first portion.

20 4740. The method of claim 4703, wherein heating the second portion of the selected section to a temperature sufficient to allow synthesis gas generation and providing a second synthesis gas generating fluid to the second portion of the selected section comprises introducing steam into the second portion.

25 4741. The method of claim 4703, further comprising controlling the heating of the first portion of selected section and provision of the first synthesis gas generating fluid to maintain a temperature within the first portion of the selected section above the temperature sufficient to generate synthesis gas.

30 4742. The method of claim 4703, further comprising controlling the heating of the second portion of selected section and provision of the second synthesis gas generating

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fluid to maintain a temperature within the second portion of the selected section above the temperature sufficient to generate synthesis gas.

4743. The method of claim 4703, wherein the first synthesis gas generating fluid comprises liquid water.

4744. The method of claim 4703, wherein the second synthesis gas generating fluid comprises liquid water.

4745. The method of claim 4703, wherein the first synthesis gas generating fluid comprises steam.

4746. The method of claim 4703, wherein the second synthesis gas generating fluid comprises steam.

4747. The method of claim 4703, wherein the first synthesis gas generating fluid comprises water and carbon dioxide, wherein the carbon dioxide inhibits production of carbon dioxide from the selected section.

4748. The method of claim 4747, wherein a portion of the carbon dioxide within the first synthesis gas generating fluid comprises carbon dioxide removed from the formation.

4749. The method of claim 4703, wherein the second synthesis gas generating fluid comprises water and carbon dioxide, wherein the carbon dioxide inhibits production of carbon dioxide from the selected section.

4750. The method of claim 4749, wherein a portion of the carbon dioxide within the second synthesis gas generating fluid comprises carbon dioxide removed from the formation.



4751. The method of claim 4703, wherein the first synthesis gas generating fluid comprises carbon dioxide, and wherein a portion of the carbon dioxide reacts with carbon in the formation to generate carbon monoxide.

5 4752. The method of claim 4751, wherein a portion of the carbon dioxide within the first synthesis gas generating fluid comprises carbon dioxide removed from the formation.

10 4753. The method of claim 4703, wherein the second synthesis gas generating fluid comprises carbon dioxide, and wherein a portion of the carbon dioxide reacts with carbon in the formation to generate carbon monoxide.

15 4754. The method of claim 4753, wherein a portion of the carbon dioxide within the second synthesis gas generating fluid comprises carbon dioxide removed from the formation.

20 4755. The method of claim 4703, wherein providing the first synthesis gas generating fluid to the first portion of the selected section comprises raising a water table of the formation to allow water to flow into the first portion of the selected section.

4756. The method of claim 4703, wherein providing the second synthesis gas generating fluid to the second portion of the selected section comprises raising a water table of the formation to allow water to flow into the second portion of the selected section.

25 4757. The method of claim 4703, wherein the first synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers less than 5, and wherein at least a portion of the hydrocarbons are subjected to a reaction within the first portion of the selected section to increase a  $H_2$  concentration within the produced first synthesis gas.

30 4758. The method of claim 4703, wherein the second synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers less than 5, and wherein at

least a portion of the hydrocarbons are subjected to a reaction within the second portion of the selected section to increase a H<sub>2</sub> concentration within the produced second synthesis gas.

5 4759. The method of claim 4703, wherein the first synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers greater than 4, and wherein at least a portion of the hydrocarbons react within the first portion of the selected section to increase an energy content of the produced first synthesis gas.

10 4760. The method of claim 4703, wherein the second synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers greater than 4, and wherein at least a portion of the hydrocarbons react within at least the second portion of the selected section to increase an energy content of the second produced synthesis gas.

15 4761. The method of claim 4703, further comprising maintaining a pressure within the formation during synthesis gas generation, and passing produced blended synthesis gas through a turbine to generate electricity.

20 4762. The method of claim 4703, further comprising generating electricity from the blended synthesis gas using a fuel cell.

25 4763. The method of claim 4703, further comprising generating electricity from the blended synthesis gas using a fuel cell, separating carbon dioxide from a fluid exiting the fuel cell, and storing a portion of the separated carbon dioxide within a spent section of the formation.

4764. The method of claim 4703, further comprising using a portion of the blended synthesis gas as a combustion fuel for the one or more heat sources.

30 4765. The method of claim 4703, further comprising using a portion of the first synthesis gas as a combustion fuel for the one or more heat sources.

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4766. The method of claim 4703, further comprising using a portion of the second synthesis gas as a combustion fuel for the one or more heat sources.

5 4767. The method of claim 4703, further comprising using a portion of the blended synthesis gas as a combustion fuel for the one or more heat sources.

4768. A method of treating a hydrocarbon containing formation in situ, comprising:  
providing heat from one or more heat sources to at least a portion of the  
10 formation;

allowing the heat to transfer from the one or more heat sources to a selected section of the formation such that the heat from the one or more heat sources pyrolyzes at least some of the hydrocarbons within the selected section of the formation;

producing pyrolysis products from the formation;

15 heating at least a portion of the selected section to a temperature sufficient to generate synthesis gas;

controlling a temperature of at least a portion of the selected section to generate synthesis gas having a selected  $H_2$  to CO ratio;

20 providing a synthesis gas generating fluid to at least the portion of the selected section to generate synthesis gas; and

producing a portion of the synthesis gas from the formation.

4769. The method of claim 4768, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from at least the two heat  
25 sources pyrolyzes at least some hydrocarbons within the selected section of the formation.

4770. The method of claim 4768, wherein the selected ratio is controlled to be approximately 2:1  $H_2$  to CO.

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4771. The method of claim 4768, wherein the selected ratio is controlled to range from approximately 1.8:1 to approximately 2.2:1 H<sub>2</sub> to CO.

4772. The method of claim 4768, wherein the selected ratio is controlled to be approximately 3:1 H<sub>2</sub> to CO.

4773. The method of claim 4768, wherein the selected ratio is controlled to range from approximately 2.8:1 to approximately 3.2:1 H<sub>2</sub> to CO.

4774. The method of claim 4768, further comprising providing at least a portion of the produced synthesis gas to a condensable hydrocarbon synthesis process to produce condensable hydrocarbons.

4775. The method of claim 4774, wherein the condensable hydrocarbon synthesis process comprises a Fischer-Tropsch process.

4776. The method of claim 4775, further comprising cracking at least a portion of the condensable hydrocarbons to form middle distillates.

4777. The method of claim 4768, further comprising providing at least a portion of the produced synthesis gas to a catalytic methanation process to produce methane.

4778. The method of claim 4768, further comprising providing at least a portion of the produced synthesis gas to a methanol-synthesis process to produce methanol.

4779. The method of claim 4768, further comprising providing at least a portion of the produced synthesis gas to a gasoline-synthesis process to produce gasoline.

4780. The method of claim 4768, further comprising allowing the heat to transfer from the one or more heat sources to the selected section to substantially uniformly increase a permeability of the selected section.

4781. The method of claim 4768, further comprising controlling heat transfer from the one or more heat sources to produce a permeability within the selected section of greater than about 100 millidarcy.

4782. The method of claim 4768, further comprising heating at least the portion of the selected section when providing the synthesis gas generating fluid to inhibit temperature decrease within the selected section during synthesis gas generation.

4783. The method of claim 4768, wherein the temperature sufficient to allow synthesis gas generation is within a range from approximately 400 °C to approximately 1200 °C.

4784. The method of claim 4768, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation comprises:

heating zones adjacent to wellbores of one or more heat sources with heaters disposed in the wellbores, wherein the heaters are configured to raise temperatures of the zones to temperatures sufficient to support reaction of carbon-containing material within the zones with an oxidizing fluid;

introducing the oxidizing fluid to the zones substantially by diffusion;

allowing the oxidizing fluid to react with at least a portion of the carbon-containing material within the zones to produce heat in the zones; and transferring heat from the zones to the selected section.

4785. The method of claim 4768, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation comprises:

introducing an oxidizing fluid into the formation through a wellbore;

transporting the oxidizing fluid substantially by convection into the portion of the selected section, wherein the portion of the selected section is at a temperature sufficient to support an oxidation reaction with the oxidizing fluid; and

reacting the oxidizing fluid within the portion of the selected section to generate heat and raise the temperature of the portion.

4786. The method of claim 4768, wherein the one or more heat sources comprise one or more electrical heaters disposed in the formation.

5 4787. The method of claim 4768, wherein the one or more heat sources comprises one or more natural distributor combustors.

10 4788. The method of claim 4768, wherein the one or more heat sources comprise one or more heater wells, wherein at least one heater well comprises a conduit disposed within the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

15 4789. The method of claim 4768, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation and providing a synthesis gas generating fluid to at least the portion of the selected section comprises introducing steam into the portion.

20 4790. The method of claim 4768, further comprising controlling the heating of at least the portion of selected section and provision of the synthesis gas generating fluid to maintain a temperature within at least the portion of the selected section above the temperature sufficient to generate synthesis gas.

25 4791. The method of claim 4768, wherein the synthesis gas generating fluid comprises liquid water.

4792. The method of claim 4768, wherein the synthesis gas generating fluid comprises steam.

30 4793. The method of claim 4768, wherein the synthesis gas generating fluid comprises water and carbon dioxide, wherein the carbon dioxide inhibits production of carbon dioxide from the selected section.

4794. The method of claim 4793, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

5 4795. The method of claim 4768, wherein the synthesis gas generating fluid comprises carbon dioxide, and wherein a portion of the carbon dioxide reacts with carbon in the formation to generate carbon monoxide.

10 4796. The method of claim 4795, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

15 4797. The method of claim 4768, wherein providing the synthesis gas generating fluid to at least the portion of the selected section comprises raising a water table of the formation to allow water to flow into the at least the portion of the selected section.

20 4798. The method of claim 4768, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers less than 5, and wherein at least a portion of the hydrocarbons are subjected to a reaction within at least the portion of the selected section to increase a  $H_2$  concentration within the produced synthesis gas.

25 4799. The method of claim 4768, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers greater than 4, and wherein at least a portion of the hydrocarbons react within at least the portion of the selected section to increase an energy content of the produced synthesis gas.

30 4800. The method of claim 4768, further comprising maintaining a pressure within the formation during synthesis gas generation, and passing produced synthesis gas through a turbine to generate electricity.

4801. The method of claim 4768, further comprising generating electricity from the synthesis gas using a fuel cell.

4802. The method of claim 4768, further comprising generating electricity from the synthesis gas using a fuel cell, separating carbon dioxide from a fluid exiting the fuel cell, and storing a portion of the separated carbon dioxide within a spent section of the formation.

4803. The method of claim 4768, further comprising using a portion of the synthesis gas as a combustion fuel for the one or more heat sources.

4804. A method of treating a hydrocarbon containing formation in situ, comprising:  
providing heat from one or more heat sources to at least a portion of the formation;  
allowing the heat to transfer from the one or more heat sources to a selected section of the formation such that the heat from the one or more heat sources pyrolyzes at least some of the hydrocarbons within the selected section of the formation;  
producing pyrolysis products from the formation;  
heating at least a portion of the selected section to a temperature sufficient to generate synthesis gas;  
controlling a temperature in or proximate to a synthesis gas production well to generate synthesis gas having a selected H<sub>2</sub> to CO ratio;  
providing a synthesis gas generating fluid to at least the portion of the selected section to generate synthesis gas; and  
producing synthesis gas from the formation.

4805. The method of claim 4804, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from at least the two heat sources pyrolyzes at least some hydrocarbons within the selected section of the formation.

4806. The method of claim 4804, wherein the selected ratio is controlled to be approximately 2:1 H<sub>2</sub> to CO.



4807. The method of claim 4804, wherein the selected ratio is controlled to range from approximately 1.8:1 to approximately 2.2:1 H<sub>2</sub> to CO.

5 4808. The method of claim 4804, wherein the selected ratio is controlled to be approximately 3:1 H<sub>2</sub> to CO.

4809. The method of claim 4804, wherein the selected ratio is controlled to range from approximately 2.8:1 to approximately 3.2:1 H<sub>2</sub> to CO.

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4810. The method of claim 4804, further comprising providing at least a portion of the produced synthesis gas to a condensable hydrocarbon synthesis process to produce condensable hydrocarbons.

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4811. The method of claim 4810, wherein the condensable hydrocarbon synthesis process comprises a Fischer-Tropsch process.

4812. The method of claim 4811, further comprising cracking at least a portion of the condensable hydrocarbons to form middle distillates.

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4813. The method of claim 4804, further comprising providing at least a portion of the produced synthesis gas to a catalytic methanation process to produce methane.

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4814. The method of claim 4804, further comprising providing at least a portion of the produced synthesis gas to a methanol-synthesis process to produce methanol.

4815. The method of claim 4804, further comprising providing at least a portion of the produced synthesis gas to a gasoline-synthesis process to produce gasoline.

4816. The method of claim 4804, further comprising allowing the heat to transfer from the one or more heat sources to the selected section to substantially uniformly increase a permeability of the selected section.

5 4817. The method of claim 4804, further comprising controlling heat transfer from the one or more heat sources to produce a permeability within the selected section of greater than about 100 millidarcy.

10 4818. The method of claim 4804, further comprising heating at least the portion of the selected section when providing the synthesis gas generating fluid to inhibit temperature decrease within the selected section during synthesis gas generation.

15 4819. The method of claim 4804, wherein the temperature sufficient to allow synthesis gas generation is within a range from approximately 400 °C to approximately 1200 °C.

4820. The method of claim 4804, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation comprises:

20 heating zones adjacent to wellbores of one or more heat sources with heaters disposed in the wellbores, wherein the heaters are configured to raise temperatures of the zones to temperatures sufficient to support reaction of carbon-containing material within the zones with an oxidizing fluid;

introducing the oxidizing fluid to the zones substantially by diffusion;

allowing the oxidizing fluid to react with at least a portion of the carbon-containing material within the zones to produce heat in the zones; and

25 transferring heat from the zones to the selected section.

4821. The method of claim 4804, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation comprises:

~~introducing an oxidizing fluid into the formation through a wellbore;~~

transporting the oxidizing fluid substantially by convection into the portion of the selected section, wherein the portion of the selected section is at a temperature sufficient to support an oxidization reaction with the oxidizing fluid; and

reacting the oxidizing fluid within the portion of the selected section to generate heat and raise the temperature of the portion.

4822. The method of claim 4804, wherein the one or more heat sources comprise one or more electrical heaters disposed in the formation.

4823. The method of claim 4804, wherein the one or more heat sources comprises one or more natural distributor combustors.

4824. The method of claim 4804, wherein the one or more heat sources comprise one or more heater wells, wherein at least one heater well comprises a conduit disposed within the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

4825. The method of claim 4804, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation and providing a synthesis gas generating fluid to at least the portion of the selected section comprises introducing steam into the portion.

4826. The method of claim 4804, further comprising controlling the heating of at least the portion of selected section and provision of the synthesis gas generating fluid to maintain a temperature within at least the portion of the selected section above the temperature sufficient to generate synthesis gas.

4827. The method of claim 4804, wherein the synthesis gas generating fluid comprises liquid water.

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4828. The method of claim 4804, wherein the synthesis gas generating fluid comprises steam.

4829. The method of claim 4804, wherein the synthesis gas generating fluid comprises water and carbon dioxide, wherein the carbon dioxide inhibits production of carbon dioxide from the selected section.

4830. The method of claim 4829, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

4831. The method of claim 4804, wherein the synthesis gas generating fluid comprises carbon dioxide, and wherein a portion of the carbon dioxide reacts with carbon in the formation to generate carbon monoxide.

4832. The method of claim 4831, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

4833. The method of claim 4804, wherein providing the synthesis gas generating fluid to at least the portion of the selected section comprises raising a water table of the formation to allow water to flow into the at least the portion of the selected section.

4834. The method of claim 4804, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers less than 5, and wherein at least a portion of the hydrocarbons are subjected to a reaction within at least the portion of the selected section to increase a  $H_2$  concentration within the produced synthesis gas.

4835. The method of claim 4804, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers greater than 4, and wherein at least a portion of the hydrocarbons react within at least the portion of the selected section to increase an energy content of the produced synthesis gas.

4836. The method of claim 4804, further comprising maintaining a pressure within the formation during synthesis gas generation, and passing produced synthesis gas through a turbine to generate electricity.

5 4837. The method of claim 4804, further comprising generating electricity from the synthesis gas using a fuel cell.

10 4838. The method of claim 4804, further comprising generating electricity from the synthesis gas using a fuel cell, separating carbon dioxide from a fluid exiting the fuel cell, and storing a portion of the separated carbon dioxide within a spent section of the formation.

15 4839. The method of claim 4804, further comprising using a portion of the synthesis gas as a combustion fuel for the one or more heat sources.

20 4840. A method of treating a hydrocarbon containing formation in situ, comprising:  
 providing heat from one or more heat sources to at least a portion of the formation;  
 allowing the heat to transfer from the one or more heat sources to a selected section of the formation such that the heat from the one or more heat sources pyrolyzes at least some of the hydrocarbons within the selected section of the formation;  
 producing pyrolysis products from the formation;  
 heating at least a portion of the selected section to a temperature sufficient to generate synthesis gas;  
 25 controlling a temperature of at least a portion of the selected section to generate synthesis gas having a  $H_2$  to CO ratio different than a selected  $H_2$  to CO ratio;  
 providing a synthesis gas generating fluid to at least the portion of the selected section to generate synthesis gas; and  
 producing synthesis gas from the formation;  
 30 providing at least a portion of the produced synthesis gas to a shift process wherein an amount of carbon monoxide is converted to carbon dioxide;

separating at least a portion of the carbon dioxide to obtain a gas having a selected H<sub>2</sub> to CO ratio.

4841. The method of claim 4840, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from at least the two heat sources pyrolyzes at least some hydrocarbons within the selected section of the formation.

4842. The method of claim 4840, wherein the selected ratio is controlled to be approximately 2:1 H<sub>2</sub> to CO.

4843. The method of claim 4840, wherein the selected ratio is controlled to range from approximately 1.8:1 to 2.2:1 H<sub>2</sub> to CO.

4844. The method of claim 4840, wherein the selected ratio is controlled to be approximately 3:1 H<sub>2</sub> to CO.

4845. The method of claim 4840, wherein the selected ratio is controlled to range from approximately 2.8:1 to 3.2:1 H<sub>2</sub> to CO.

4846. The method of claim 4840, further comprising providing at least a portion of the produced synthesis gas to a condensable hydrocarbon synthesis process to produce condensable hydrocarbons.

4847. The method of claim 4846, wherein the condensable hydrocarbon synthesis process comprises a Fischer-Tropsch process.

4848. The method of claim 4847, further comprising cracking at least a portion of the condensable hydrocarbons to form middle distillates.

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4849. The method of claim 4840, further comprising providing at least a portion of the produced synthesis gas to a catalytic methanation process to produce methane.

4850. The method of claim 4840, further comprising providing at least a portion of the produced synthesis gas to a methanol-synthesis process to produce methanol.

4851. The method of claim 4840, further comprising providing at least a portion of the produced synthesis gas to a gasoline-synthesis process to produce gasoline.

4852. The method of claim 4840, further comprising allowing the heat to transfer from the one or more heat sources to the selected section to substantially uniformly increase a permeability of the selected section.

4853. The method of claim 4840, further comprising controlling heat transfer from the one or more heat sources to produce a permeability within the selected section of greater than about 100 millidarcy.

4854. The method of claim 4840, further comprising heating at least the portion of the selected section when providing the synthesis gas generating fluid to inhibit temperature decrease within the selected section during synthesis gas generation.

4855. The method of claim 4840, wherein the temperature sufficient to allow synthesis gas generation is within a range from approximately 400 °C to approximately 1200 °C.

4856. The method of claim 4840, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation comprises:

heating zones adjacent to wellbores of one or more heat sources with heaters disposed in the wellbores, wherein the heaters are configured to raise temperatures of the zones to temperatures sufficient to support reaction of carbon-containing material within the zones with an oxidizing fluid;

introducing the oxidizing fluid to the zones substantially by diffusion;

allowing the oxidizing fluid to react with at least a portion of the carbon-containing material within the zones to produce heat in the zones; and transferring heat from the zones to the selected section.

5 4857. The method of claim 4840, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation comprises:

introducing an oxidizing fluid into the formation through a wellbore;

transporting the oxidizing fluid substantially by convection into the portion of the selected section, wherein the portion of the selected section is at a temperature sufficient to support an oxidation reaction with the oxidizing fluid; and

10 reacting the oxidizing fluid within the portion of the selected section to generate heat and raise the temperature of the portion.

15 4858. The method of claim 4840, wherein the one or more heat sources comprise one or more electrical heaters disposed in the formation.

4859. The method of claim 4840, wherein the one or more heat sources comprises one or more natural distributor combustors.

20 4860. The method of claim 4840, wherein the one or more heat sources comprise one or more heater wells, wherein at least one heater well comprises a conduit disposed within the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

25 4861. The method of claim 4840, wherein heating at least the portion of the selected section to a temperature sufficient to allow synthesis gas generation and providing a synthesis gas generating fluid to at least the portion of the selected section comprises introducing steam into the portion.

30 4862. The method of claim 4840, further comprising controlling the heating of at least the portion of selected section and provision of the synthesis gas generating fluid to

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maintain a temperature within at least the portion of the selected section above the temperature sufficient to generate synthesis gas.

4863. The method of claim 4840, wherein the synthesis gas generating fluid comprises liquid water.

4864. The method of claim 4840, wherein the synthesis gas generating fluid comprises steam.

4865. The method of claim 4840, wherein the synthesis gas generating fluid comprises water and carbon dioxide, wherein the carbon dioxide inhibits production of carbon dioxide from the selected section.

4866. The method of claim 4865, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

4867. The method of claim 4840, wherein the synthesis gas generating fluid comprises carbon dioxide, and wherein a portion of the carbon dioxide reacts with carbon in the formation to generate carbon monoxide.

4868. The method of claim 4867, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

4869. The method of claim 4840, wherein providing the synthesis gas generating fluid to at least the portion of the selected section comprises raising a water table of the formation to allow water to flow into the at least the portion of the selected section.

4870. The method of claim 4840, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers less than 5, and wherein at least a portion of the hydrocarbons are subjected to a reaction within at least the portion of the selected section to increase a  $H_2$  concentration within the produced synthesis gas.

4871. The method of claim 4840, wherein the synthesis gas generating fluid comprises water and hydrocarbons having carbon numbers greater than 4, and wherein at least a portion of the hydrocarbons react within at least the portion of the selected section to increase an energy content of the produced synthesis gas.

4872. The method of claim 4840, further comprising maintaining a pressure within the formation during synthesis gas generation, and passing produced synthesis gas through a turbine to generate electricity.

4873. The method of claim 4840, further comprising generating electricity from the synthesis gas using a fuel cell.

4874. The method of claim 4840, further comprising generating electricity from the synthesis gas using a fuel cell, separating carbon dioxide from a fluid exiting the fuel cell, and storing a portion of the separated carbon dioxide within a spent section of the formation.

4875. The method of claim 4840, further comprising using a portion of the synthesis gas as a combustion fuel for the one or more heat sources.

4876. A method of forming a spent portion of formation within a hydrocarbon containing formation, comprising:

heating a first portion of the formation to pyrolyze hydrocarbons within the first portion and to establish a substantially uniform permeability within the first portion; and cooling the first portion.

4877. The method of claim 4876, wherein heating the first portion comprises transferring heat to the first portion from one or more electrical heaters.

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4878. The method of claim 4876, wherein heating the first portion comprises transferring heat to the first portion from one or more natural distributor combustors.

4879. The method of claim 4876, wherein heating the first portion comprises transferring heat to the first portion from one or more flameless distributor combustors.

4880. The method of claim 4876, wherein heating the first portion comprises transferring heat to the first portion from heat transfer fluid flowing within one or more wellbores within the formation.

4881. The method of claim 4880, wherein the heat transfer fluid comprises steam.

4882. The method of claim 4880, wherein the heat transfer fluid comprises combustion products from a burner.

4883. The method of claim 4876, wherein heating the first portion comprises transferring heat to the first portion from at least two heater wells positioned within the formation, wherein the at least two heater wells are placed in a substantially regular pattern, wherein the substantially regular pattern comprises repetition of a base heater unit, and wherein the base heater unit is formed of a number of heater wells.

4884. The method of claim 4883, wherein a spacing between a pair of adjacent heater wells is within a range from about 6 m to about 15 m.

4885. The method of claim 4883, further comprising removing fluid from the formation through one or more production wells.

4886. The method of claim 4885, wherein the one or more production wells are located in a pattern, and wherein the one or more production wells are positioned substantially at centers of base heater units.

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4887. The method of claim 4883, wherein the heater unit comprises three heater wells positioned substantially at apexes of an equilateral triangle.

5 4888. The method of claim 4883, wherein the heater unit comprises four heater wells positioned substantially at apexes of a rectangle.

4889. The method of claim 4883, wherein the heater unit comprises five heater wells positioned substantially at apexes of a regular pentagon.

10 4890. The method of claim 4883, wherein the heater unit comprises six heater wells positioned substantially at apexes of a regular hexagon.

4891. The method of claim 4876, further comprising introducing water to the first portion to cool the formation.

15 4892. The method of claim 4876, further comprising removing steam from the formation.

20 4893. The method of claim 4892, further comprising using a portion of the removed steam to heat a second portion of the formation.

4894. The method of claim 4876, further comprising removing pyrolyzation products from the formation.

25 4895. The method of claim 4876, further comprising generating synthesis gas within the portion by introducing a synthesis gas generating fluid into the portion, and removing synthesis gas from the formation.

30 4896. The method of claim 4876, further comprising heating a second section of the formation to pyrolyze hydrocarbons within the second portion, removing pyrolyzation

fluid from the second portion, and storing a portion of the removed pyrolyzation fluid within the first portion.

4897. The method of claim 4896, wherein the portion of the removed pyrolyzation fluid is stored within the first portion when surface facilities that process the removed pyrolyzation fluid are not able to process the portion of the removed pyrolyzation fluid.

4898. The method of claim 4896, further comprising heating the first portion to facilitate removal of the stored pyrolyzation fluid from the first portion.

4899. The method of claim 4876, further comprising generating synthesis gas within a second portion of the formation, removing synthesis gas from the second portion, and storing a portion of the removed synthesis gas within the first portion.

4900. The method of claim 4899, wherein the portion of the removed synthesis gas from the second portion are stored within the first portion when surface facilities that process the removed synthesis gas are not able to process the portion of the removed synthesis gas.

4901. The method of claim 4899, further comprising heating the first portion to facilitate removal of the stored synthesis gas from the first portion.

4902. The method of claim 4876, further comprising removing at least a portion of carbon containing material in the first portion and, further comprising using at least a portion of the carbon containing material removed from the formation in a metallurgical application.

4903. The method of claim 4902, wherein the metallurgical application comprises steel manufacturing.

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4904. A method of sequestering carbon dioxide within a hydrocarbon containing formation, comprising:

heating a portion of the formation to increase permeability and form a substantially uniform permeability within the portion;

5 allowing the portion to cool; and  
storing carbon dioxide within the portion.

4905. The method of claim 4904, wherein the permeability of the portion is increased to over 100 millidarcy

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4906. The method of claim 4904, further comprising raising a water level within the portion to inhibit migration of the carbon dioxide from the portion.

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4907. The method of claim 4904, further comprising heating the portion to release carbon dioxide, and removing carbon dioxide from the portion.

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4908. The method of claim 4904, further comprising pyrolyzing hydrocarbons within the portion during heating of the portion, and removing pyrolyzation product from the formation.

4909. The method of claim 4904, further comprising producing synthesis gas from the portion during the heating of the portion, and removing synthesis gas from the formation.

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4910. The method of claim 4904, wherein heating the portion comprises:

heating carbon containing material adjacent to one or more wellbores to a temperature sufficient to support oxidation of the carbon containing material with an oxidizing fluid;

introducing the oxidizing fluid to carbon containing material adjacent to the one or more wellbores to oxidize the hydrocarbons and produce heat; and

30

conveying produced heat to the portion.

4911. The method of claim 4910, wherein heating carbon containing material adjacent to the one or more wells comprises electrically heating the carbon containing material.

5 4912. The method of claim 4910, wherein the temperature sufficient to support oxidation is in a range between approximately 200°C to approximately 1200 °C.

4913. The method of claim 4904, wherein heating the portion comprises circulating heat transfer fluid through one or more heating wells within the formation.

10 4914. The method of claim 4913, wherein the heat transfer fluid comprises combustion products from a burner.

4915. The method of claim 4913, wherein the heat transfer fluid comprises steam.

15 4916. The method of claim 4904, further comprising removing fluid from the formation during heating of the formation, and combusting a portion of the removed fluid to generate heat to heat the formation.

20 4917. The method of claim 4904, further comprising using at least a portion of the carbon dioxide for hydrocarbon bed demethanation prior to storing the carbon dioxide within the portion.

4918. The method of claim 4904, further comprising using a portion of the carbon dioxide for enhanced oil recovery prior to storing the carbon dioxide within the portion.

25 4919. The method of claim 4904, wherein at least a portion of the carbon dioxide comprises carbon dioxide generated in a fuel cell.

30 4920. The method of claim 4904, wherein at least a portion of the carbon dioxide comprises carbon dioxide formed as a combustion product.

4921. The method of claim 4904, further comprising allowing the portion to cool by introducing water to the portion; and removing the water from the formation as steam.

4922. The method of claim 4921, further comprising using the steam as a heat transfer fluid to heat a second portion of the formation.

4923. The method of claim 4904, wherein storing carbon dioxide in the portion comprises adsorbing carbon dioxide to carbon containing material within the formation.

4924. The method of claim 4904, wherein storing carbon dioxide comprises passing a first fluid stream comprising the carbon dioxide and other fluid through the portion; adsorbing carbon dioxide onto carbon containing material within the formation; and removing a second fluid stream from the formation, wherein a concentration of the other fluid in the second fluid stream is greater than concentration of other fluid in the first stream due to the absence of the adsorbed carbon dioxide in the second stream.

4925. The method of claim 4904, wherein an amount of carbon dioxide stored within the portion is equal to or greater than an amount of carbon dioxide generated within the portion and removed from the formation during heating of the portion.

4926. The method of claim 4904, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, and wherein the unit of heat sources comprises a triangular pattern.

4927. The method of claim 4904, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, wherein the unit of heat sources comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.



4928. A method of in situ sequestration of carbon dioxide within a hydrocarbon containing formation in situ, comprising:

providing heat from one or more heat sources to at least a first portion of the formation;

5 allowing the heat to transfer from one or more sources to a selected section of the formation such that the heat from the one or more heat sources pyrolyzes at least some of the hydrocarbons within the selected section of the formation;

producing pyrolyzation fluids, wherein the pyrolyzation fluids comprise carbon dioxide; and

10 storing an amount of carbon dioxide in the formation, wherein the amount of stored carbon dioxide is equal to or greater than an amount of carbon dioxide within the pyrolyzation fluids.

4929. The method of claim 4928, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from at least the two heat sources pyrolyzes at least some hydrocarbons within the selected section of the formation.

4930. The method of claim 4928, wherein the carbon dioxide is stored within a spent portion of the formation.

4931. The method of claim 4928, wherein a portion of the carbon dioxide stored within the formation is carbon dioxide separated from the pyrolyzation fluids.

25 4932. The method of claim 4928, further comprising separating a portion of carbon dioxide from the pyrolyzation fluids, and using the carbon dioxide as a flooding agent in enhanced oil recovery.

30 4933. The method of claim 4928, further comprising separating a portion of carbon dioxide from the pyrolyzation fluids, and using the carbon dioxide as a synthesis gas generating fluid for the generation of synthesis gas from a section of the formation that is

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heated to a temperature sufficient to generate synthesis gas upon introduction of the  
~~synthesis gas generating fluid.~~

5 4934. The method of claim 4928, further comprising separating a portion of carbon dioxide from the pyrolyzation fluids, and using the carbon dioxide to displace hydrocarbon bed methane.

10 4935. The method of claim 4934, wherein the hydrocarbon bed is a deep hydrocarbon bed located over 760 m below ground surface.

4936. The method of claim 4934, further comprising adsorbing a portion of the carbon dioxide within the hydrocarbon bed.

15 4937. The method of claim 4928, further comprising using at least a portion of the pyrolyzation fluids as a feed stream for a fuel cell.

4938. The method of claim 4937, wherein the fuel cell generates carbon dioxide, and further comprising storing an amount of carbon dioxide equal to or greater than an amount of carbon dioxide generated by the fuel cell within the formation.

20 4939. The method of claim 4928, wherein a spent portion of the formation comprises carbon containing material within a section of the formation that has been heated and from which condensable hydrocarbons have been produced, and wherein the spent portion of the formation is at a temperature at which carbon dioxide adsorbs onto the carbon containing material.

4940. The method of claim 4928, further comprising raising a water level within the spent portion to inhibit migration of the carbon dioxide from the portion.

30 4941. The method of claim 4928, wherein producing fluids from the formation comprises removing pyrolyzation products from the formation.

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4942. The method of claim 4928, wherein producing fluids from the formation comprises heating the selected section to a temperature sufficient to generate synthesis gas; introducing a synthesis gas generating fluid into the selected section; and removing synthesis gas from the formation.

4943. The method of claim 4942, wherein the temperature sufficient to generate synthesis gas ranges from about 400 °C to about 1200 °C.

4944. The method of claim 4942, wherein heating the selected section comprises introducing an oxidizing fluid into the selected section, reacting the oxidizing fluid within the selected section to heat the selected section.

4945. The method of claim 4942, wherein heating the selected section comprises:  
heating carbon containing material adjacent to one or more wellbores to a temperature sufficient to support oxidation of the carbon containing material with an oxidant;  
introducing the oxidant to carbon containing material adjacent to the one or more wellbores to oxidize the hydrocarbons and produce heat; and  
conveying produced heat to the portion.

4946. The method of claim 4928, wherein the spent portion of the formation comprises a substantially uniform permeability created by heating the spent formation and removing fluid during formation of the spent portion.

4947. The method of claim 4928, wherein the one or more heat sources comprise electrical heaters.

4948. The method of claim 4928, wherein the one or more heat sources comprise flameless distributor combustors.

4949. The method of claim 4948, wherein a portion of fuel for the one or more flameless distributor combustors is obtained from the formation.

5 4950. The method of claim 4928, wherein the one or more heat sources comprise heater wells in the formation through which heat transfer fluid is circulated.

4951. The method of claim 4950, wherein the heat transfer fluid comprises combustion products.

10 4952. The method of claim 4950, wherein the heat transfer fluid comprises steam.

4953. The method of claim 4928, wherein condensable hydrocarbons are produced under pressure, and further comprising generating electricity by passing a portion of the produced fluids through a turbine.

15 4954. The method of claim 4928, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, and wherein the unit of heat sources comprises a triangular pattern.

20 4955. The method of claim 4928, further comprising providing heat from three or more heat sources to at least a portion of the formation, wherein three or more of the heat sources are located in the formation in a unit of heat sources, wherein the unit of heat sources comprises a triangular pattern, and wherein a plurality of the units are repeated  
25 over an area of the formation to form a repetitive pattern of units.

4956. A method for in situ production of energy from a hydrocarbon containing formation, comprising:  
providing heat from one or more heat sources to at least a portion of the  
30 formation;

allowing the heat to transfer from the one or more heat sources to a selected section of the formation such that the heat from the one or more heat sources pyrolyzes at least a portion of the hydrocarbons within the selected section of the formation;

producing pyrolysis products from the formation;

5 providing at least a portion of the pyrolysis products to a reformer to generate synthesis gas;

producing the synthesis gas from the reformer;

providing at least a portion of the produced synthesis gas to a fuel cell to produce electricity, wherein the fuel cell produces a carbon dioxide containing exit stream; and

10 storing at least a portion of the carbon dioxide in the carbon dioxide containing exit stream in a subsurface formation.

4957. The method of claim 4956, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from at least the two heat sources pyrolyzes at least some hydrocarbons within the selected section of the formation.

4958. The method of claim 4956, wherein at least a portion of the pyrolysis products are used as fuel in the reformer.

4959. The method of claim 4956, wherein the synthesis gas comprises substantially of H<sub>2</sub>.

4960. The method of claim 4956, wherein the subsurface formation is a spent portion of the formation.

4961. The method of claim 4956, wherein the subsurface formation is an oil reservoir.

4962. The method of claim 4961, wherein at least a portion of the carbon dioxide is used as a drive fluid for enhanced oil recovery in the oil reservoir.

4963. The method of claim 4956, wherein the subsurface formation is a hydrocarbon formation.

4964. The method of claim 4956, wherein at least a portion of the carbon dioxide is used to produce methane from the hydrocarbon formation.

4965. The method of claim 4963, wherein the coal formation is located over about 760 m below ground surface.

4966. The method of claim 4964, further comprising sequestering at least a portion of the carbon dioxide within the hydrocarbon formation.

4967. The method of claim 4956, wherein the reformer produces a reformer carbon dioxide containing exit stream.

4968. The method of claim 4966, further comprising storing at least a portion of the carbon dioxide in the reformer carbon dioxide containing exit stream in the subsurface formation.

4969. The method of claim 4968, wherein the subsurface formation is a spent portion of the formation.

4970. The method of claim 4968, wherein the subsurface formation is an oil reservoir.

4971. The method of claim 4970, wherein at least a portion of the carbon dioxide in the reformer carbon dioxide containing exit stream is used as a drive fluid for enhanced oil recovery in the oil reservoir.

4972. The method of claim 4968, wherein the subsurface formation is a hydrocarbon formation.

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4973. The method of claim 4872, wherein at least a portion of the carbon dioxide in the reformer carbon dioxide containing exit stream is used to produce methane from the hydrocarbon formation.

5 4974. The method of claim 4972, wherein the hydrocarbon formation is located over about 760 m below ground surface.

10 4975. The method of claim 4973, further comprising sequestering at least a portion of the carbon dioxide in the reformer carbon dioxide containing exit stream within the hydrocarbon formation.

4976. The method of claim 4956, wherein the fuel cell is a molten carbonate fuel cell.

15 4977. The method of claim 4956, wherein the fuel cell is a solid oxide fuel cell.

4978. The method of claim 4956, further comprising using a portion of the produced electricity to power electrical heaters within the formation.

20 4979. The method of claim 4956, further comprising using a portion of the produced pyrolysis products as a feed stream for the fuel cell.

4980. The method of claim 4956, wherein the one or more heat sources comprise one or more electrical heaters disposed in the formation.

25 4981. The method of claim 4956, wherein the one or more heat sources comprise one or more flameless distributor combustors disposed in the formation.

30 4982. The method of claim 4981, wherein a portion of fuel for the flameless distributor combustors is obtained from the formation.

4983. The method of claim 4956, wherein the one or more heat sources comprise one or more heater wells, wherein at least one heater well comprises a conduit disposed within the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

4984. The method of claim 4956, further comprising using a portion of the synthesis gas as a combustion fuel for the one or more heat sources.

4985. A method for producing ammonia using a carbon containing formation, comprising:

separating air to produce an O<sub>2</sub> rich stream and a N<sub>2</sub> rich stream;

heating a selected section of the formation to a temperature sufficient to support reaction of carbon-containing material in the formation to form synthesis gas;

providing synthesis gas generating fluid and at least a portion of the O<sub>2</sub> rich stream to the selected section;

allowing the synthesis gas generating fluid and O<sub>2</sub> in the O<sub>2</sub> rich stream to react with at least a portion of the carbon-containing material in the formation to generate synthesis gas;

producing synthesis gas from the formation, wherein the synthesis gas comprises H<sub>2</sub> and CO;

providing at least a portion of the H<sub>2</sub> in the synthesis gas to an ammonia synthesis process;

providing N<sub>2</sub> to the ammonia synthesis process; and

using the ammonia synthesis process to generate ammonia.

4986. The method of claim 4985, wherein the ratio of the H<sub>2</sub> to N<sub>2</sub> provided to the ammonia synthesis process is approximately 3:1.

4987. The method of claim 4985, wherein the ratio of the H<sub>2</sub> to N<sub>2</sub> provided to the ammonia synthesis process ranges from approximately 2.8:1 to approximately 3.2:1.



4988. The method of claim 4985, wherein the temperature sufficient to support reaction of carbon-containing material in the formation to form synthesis gas ranges from approximately 400 °C to approximately 1200 °C.

4989. The method of claim 4985, further comprising separating at least a portion of carbon dioxide in the synthesis gas from at least a portion of the synthesis gas.

4990. The method of claim 4989, wherein the carbon dioxide is separated from the synthesis gas by an amine separator.

4991. The method of claim 4990, further comprising providing at least a portion of the carbon dioxide to a urea synthesis process to produce urea.

4992. The method of claim 4985, wherein at least a portion of the N<sub>2</sub> stream is used to condense hydrocarbons with 4 or more carbon atoms from a pyrolyzation fluid.

4993. The method of claim 4985, wherein at least a portion of the N<sub>2</sub> rich stream is provided to the ammonia synthesis process.

4994. The method of claim 4985, wherein the air is separated by cryogenic distillation.

4995. The method of claim 4985, wherein the air is separated by membrane separation.

4996. The method of claim 4985, wherein fluids produced during pyrolysis of a hydrocarbon containing formation comprise ammonia and, further comprising adding at least a portion of such ammonia to the ammonia generated from the ammonia synthesis process.

4997. The method of claim 4985, wherein fluids produced during pyrolysis of a hydrocarbon formation are hydrotreated and at least some ammonia is produced during

hydrotreating, and, further comprising adding at least a portion of such ammonia to the ammonia generated from the ammonia synthesis process.

4998. The method of claim 4985, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea.

4999. The method of claim 4985, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea and, further comprising providing carbon dioxide from the formation to the urea synthesis process.

5000. The method of claim 4985, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea and, further comprising shifting at least a portion of the carbon monoxide to carbon dioxide in a shift process, and further comprising providing at least a portion of the carbon dioxide from the shift process to the urea synthesis process.

5001. The method of claim 4985, wherein heating the selected section of the formation to a temperature to support reaction of carbon containing material in the formation to form synthesis gas comprises:

heating zones adjacent to wellbores of one or more heat sources with heaters disposed in the wellbores, wherein the heaters are configured to raise temperatures of the zones to temperatures sufficient to support reaction of carbon-containing material within the zones with  $O_2$  in the  $O_2$  rich stream;

introducing the  $O_2$  to the zones substantially by diffusion;

allowing  $O_2$  in the  $O_2$  rich stream to react with at least a portion of the carbon-containing material within the zones to produce heat in the zones; and

transferring heat from the zones to the selected section.

5002. The method of claim 5001, wherein temperatures sufficient to support reaction of carbon-containing material within the zones with  $O_2$  range from approximately 200 °C to approximately 1200 °C.

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5003. The method of claim 5001, wherein the one or more heat sources comprises one or more electrical heaters disposed in the formation.

5 5004. The method of claim 5001, wherein the one or more heat sources comprises one or more natural distributor combustors.

10 5005. The method of claim 5001, wherein the one or more heat sources comprise one or more heater wells, wherein at least one heater well comprises a conduit disposed within the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

15 5006. The method of claim 5001, further comprising using a portion of the synthesis gas as a combustion fuel for the one or more heat sources.

20 5007. The method of claim 4985, wherein heating the selected section of the formation to a temperature to support reaction of carbon containing material in the formation to form synthesis gas comprises:

introducing the O<sub>2</sub> rich stream into the formation through a wellbore;  
transporting O<sub>2</sub> in the O<sub>2</sub> rich stream substantially by convection into the portion of the selected section, wherein the portion of the selected section is at a temperature sufficient to support an oxidization reaction with O<sub>2</sub> in the O<sub>2</sub> rich stream; and  
reacting the O<sub>2</sub> within the portion of the selected section to generate heat and raise the temperature of the portion.

25 5008. The method of claim 5008, wherein the temperature sufficient to support an oxidization reaction with O<sub>2</sub> ranges from approximately 200 °C to approximately 1200 °C.

30 5009. The method of claim 5008, wherein the one or more heat sources comprises one or more electrical heaters disposed in the formation.

5010. The method of claim 5008, wherein the one or more heat sources comprises one or more natural distributor combustors.

5 5011. The method of claim 5008, wherein the one or more heat sources comprise one or more heater wells, wherein at least one heater well comprises a conduit disposed within the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

10 5012. The method of claim 5008, further comprising using a portion of the synthesis gas as a combustion fuel for the one or more heat sources.

5013. The method of claim 4985, further comprising controlling the heating of at least the portion of the selected section and provision of the synthesis gas generating fluid to maintain a temperature within at least the portion of the selected section above the temperature sufficient to generate synthesis gas.

5014. The method of claim 4985, wherein the synthesis gas generating fluid comprises liquid water.

20 5015. The method of claim 4985, wherein the synthesis gas generating fluid comprises steam.

5016. The method of claim 4985, wherein the synthesis gas generating fluid comprises water and carbon dioxide wherein the carbon dioxide inhibits production of carbon dioxide from the selected section.

25 5017. The method of claim 5016, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

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5018. The method of claim 4985, wherein the synthesis gas generating fluid comprises carbon dioxide, and wherein a portion of the carbon dioxide reacts with carbon in the formation to generate carbon monoxide.

5 5019. The method of claim 5018, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

10 5020. The method of claim 4985, wherein providing the synthesis gas generating fluid to at least the portion of the selected section comprises raising a water table of the formation to allow water to flow into the at least the portion of the selected section.

5021. A method for producing ammonia using a carbon containing formation, comprising:

15 generating a first ammonia feed stream from a first portion of the formation;  
generating a second ammonia feed stream from a second portion of the formation, wherein the second ammonia feed stream has a  $H_2$  to  $N_2$  ratio greater than a  $H_2$  to  $N_2$  ratio of the first ammonia feed stream;

20 blending at least a portion of the first ammonia feed stream with at least a portion of the second ammonia feed stream to produce a blended ammonia feed stream having a selected  $H_2$  to  $N_2$  ratio;

providing the blended ammonia feed stream to an ammonia synthesis process; and using the ammonia synthesis process to generate ammonia.

25 5022. The method of claim 5021, wherein the selected ratio is approximately 3:1.

5023. The method of claim 5021, wherein the selected ratio ranges from approximately 2.8:1 to approximately 3.2:1.

30 5024. The method of claim 5021, further comprising separating at least a portion of carbon dioxide in the first ammonia feed stream from at least a portion of the first ammonia feed stream.

5025. The method of claim 5024, wherein the carbon dioxide is separated from the first ammonia feed stream by an amine separator.

5 5026. The method of claim 5025, further comprising providing at least a portion of the carbon dioxide to a urea synthesis process.

10 5027. The method of claim 5021, further comprising separating at least a portion of carbon dioxide in the blended ammonia feed stream from at least a portion of the blended ammonia feed stream.

5028. The method of claim 5027, wherein the carbon dioxide is separated from the blended ammonia feed stream by an amine separator.

15 5029. The method of claim 5028, further comprising providing at least a portion of the carbon dioxide to a urea synthesis process

20 5030. The method of claim 5021, further comprising separating at least a portion of carbon dioxide in the second ammonia feed stream from at least a portion of the second ammonia feed stream.

5031. The method of claim 5030, wherein the carbon dioxide is separated from the second ammonia feed stream by an amine separator.

25 5032. The method of claim 5031, further comprising providing at least a portion of the carbon dioxide to a urea synthesis process.

30 5033. The method of claim 5021, wherein fluids produced during pyrolysis of a hydrocarbon containing formation comprise ammonia and, further comprising adding at least a portion of such ammonia to the ammonia generated from the ammonia synthesis process.

5034. The method of claim 5021, wherein fluids produced during pyrolysis of a hydrocarbon formation are hydrotreated and at least some ammonia is produced during hydrotreating, and further comprising adding at least a portion of such ammonia to the ammonia generated from the ammonia synthesis process.

5035. The method of claim 5021, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea.

5036. The method of claim 5021, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea and, further comprising providing carbon dioxide from the formation to the urea synthesis process.

5037. The method of claim 5021, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea and further comprising shifting at least a portion of carbon monoxide in the blended ammonia feed stream to carbon dioxide in a shift process, and further comprising providing at least a portion of the carbon dioxide from the shift process to the urea synthesis process.

5038. A method for producing ammonia using a carbon containing formation, comprising:

heating a selected section of the formation to a temperature sufficient to support reaction of carbon-containing material in the formation to form synthesis gas;

providing a synthesis gas generating fluid and an O<sub>2</sub> rich stream to the selected section, wherein the amount of N<sub>2</sub> in the O<sub>2</sub> rich stream is sufficient to generate synthesis gas having a selected ratio of H<sub>2</sub> to N<sub>2</sub>;

allowing the synthesis gas generating fluid and O<sub>2</sub> in the O<sub>2</sub> rich stream to react with at least a portion of the carbon-containing material in the formation to generate synthesis gas having a selected ratio of H<sub>2</sub> to N<sub>2</sub>;

producing the synthesis gas from the formation;

providing at least a portion of the H<sub>2</sub> and N<sub>2</sub> in the synthesis gas to an ammonia synthesis process;

using the ammonia synthesis process to generate ammonia.

5 5039. The method of claim 5038, further comprising controlling a temperature of at least a portion of the selected section to generate synthesis gas having the selected H<sub>2</sub> to N<sub>2</sub> ratio.

5040. The method of claim 5038, wherein the selected ratio is approximately 3:1.

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5041. The method of claim 5038, wherein the selected ratio ranges from approximately 2.8:1 to 3.2:1.

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5042. The method of claim 5038, wherein the temperature sufficient to support reaction of carbon-containing material in the formation to form synthesis gas ranges from approximately 400 °C to approximately 1200 °C.

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5043. The method of claim 5038, wherein the O<sub>2</sub> stream and N<sub>2</sub> stream are obtained by cryogenic separation of air.

5044. The method of claim 5038, wherein the O<sub>2</sub> stream and N<sub>2</sub> stream are obtained by membrane separation of air.

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5045. The method of claim 5038, further comprising separating at least a portion of carbon dioxide in the synthesis gas from at least a portion of the synthesis gas.

5046. The method of claim 5045, wherein the carbon dioxide is separated from the synthesis gas by an amine separator.

30

5047. The method of claim 5046, further comprising providing at least a portion of the carbon dioxide to a urea synthesis process.



5048. The method of claim 5038, wherein fluids produced during pyrolysis of a hydrocarbon containing formation comprise ammonia and, further comprising adding at least a portion of such ammonia to the ammonia generated from the ammonia synthesis process.

5049. The method of claim 5038, wherein fluids produced during pyrolysis of a hydrocarbon formation are hydrotreated and at least some ammonia is produced during hydrotreating, and further comprising adding at least a portion of such ammonia to the ammonia generated from the ammonia synthesis process.

5050. The method of claim 5038, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea.

5051. The method of claim 5038, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea and, further comprising providing carbon dioxide from the formation to the urea synthesis process.

5052. The method of claim 5038, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea and further comprising shifting at least a portion of carbon monoxide in the synthesis gas to carbon dioxide in a shift process, and further comprising providing at least a portion of the carbon dioxide from the shift process to the urea synthesis process.

5053. The method of claim 5038, wherein heating a selected section of the formation to a temperature to support reaction of carbon containing material in the formation to form synthesis gas comprises:

heating zones adjacent to wellbores of one or more heat sources with heaters disposed in the wellbores, wherein the heaters are configured to raise temperatures of the zones to temperatures sufficient to support reaction of carbon-containing material within the zones with  $O_2$  in the  $O_2$  rich stream;

introducing the O<sub>2</sub> to the zones substantially by diffusion;  
allowing O<sub>2</sub> in the O<sub>2</sub> rich stream to react with at least a portion of the carbon-  
containing material within the zones to produce heat in the zones; and  
transferring heat from the zones to the selected section.

5  
5054. The method of claim 5053, wherein temperatures sufficient to support reaction of  
carbon-containing material within the zones with O<sub>2</sub> range from approximately 200 °C to  
approximately 1200 °C.

10  
5055. The method of claim 5053, wherein the one or more heat sources comprises one  
or more electrical heaters disposed in the formation.

15  
5056. The method of claim 5053, wherein the one or more heat sources comprises one  
or more natural distributor combustors.

20  
5057. The method of claim 5053, wherein the one or more heat sources comprise one or  
more heater wells, wherein at least one heater well comprises a conduit disposed within  
the formation, and further comprising heating the conduit by flowing a hot fluid through  
the conduit.

25  
5058. The method of claim 5053, further comprising using a portion of the synthesis gas  
as a combustion fuel for the one or more heat sources.

30  
5059. The method of claim 5038, wherein heating the selected section of the formation  
to a temperature to support reaction of carbon containing material in the formation to  
form synthesis gas comprises:

introducing the O<sub>2</sub> rich stream into the formation through a wellbore;  
transporting O<sub>2</sub> in the O<sub>2</sub> rich stream substantially by convection into the portion  
of the selected section, wherein the portion of the selected section is at a temperature  
sufficient to support an oxidization reaction with O<sub>2</sub> in the O<sub>2</sub> rich stream; and

reacting the O<sub>2</sub> within the portion of the selected section to generate heat and raise the temperature of the portion.

5 5060. The method of claim 5059, wherein the temperature sufficient to support an oxidization reaction with O<sub>2</sub> ranges from approximately 200 °C to approximately 1200 °C.

10 5061. The method of claim 5059, wherein the one or more heat sources comprises one or more electrical heaters disposed in the formation.

15 5062. The method of claim 5059, wherein the one or more heat sources comprises one or more natural distributor combustors.

20 5063. The method of claim 5059, wherein the one or more heat sources comprise one or more heater wells, wherein at least one heater well comprises a conduit disposed within the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

25 5064. The method of claim 5059, further comprising using a portion of the synthesis gas as a combustion fuel for the one or more heat sources.

30 5065. The method of claim 5038, further comprising controlling the heating of at least the portion of the selected section and provision of the synthesis gas generating fluid to maintain a temperature within at least the portion of the selected section above the temperature sufficient to generate synthesis gas.

5066. The method of claim 5038, wherein the synthesis gas generating fluid comprises liquid water.

5067. The method of claim 5038, wherein the synthesis gas generating fluid comprises steam.

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5068. The method of claim 5038, wherein the synthesis gas generating fluid comprises water and carbon dioxide, wherein the carbon dioxide inhibits production of carbon dioxide from the selected section.

5069. The method of claim 5068, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

5070. The method of claim 5038, wherein the synthesis gas generating fluid comprises carbon dioxide, and wherein a portion of the carbon dioxide reacts with carbon in the formation to generate carbon monoxide.

5071. The method of claim 5070, wherein a portion of the carbon dioxide within the synthesis gas generating fluid comprises carbon dioxide removed from the formation.

5072. The method of claim 5038, wherein providing the synthesis gas generating fluid to at least the portion of the selected section comprises raising a water table of the formation to allow water to flow into the at least the portion of the selected section.

5073. A method for producing ammonia using a carbon containing formation, comprising:

- providing a first stream comprising  $N_2$  and carbon dioxide to the formation;
- allowing at least a portion of the carbon dioxide in the first stream to adsorb in the formation;
- producing a second stream from the formation, wherein the second stream comprises a lower percentage of carbon dioxide than the first stream;
- providing at least a portion of the  $N_2$  in the second stream to an ammonia synthesis process.

5074. The method of claim 5073, wherein the second stream comprises  $H_2$  from the formation.

5075. The method of claim 5073, wherein the first stream is produced from a carbon containing formation.

5 5076. The method of claim 5075, wherein the first stream is generated by reacting a oxidizing fluid with carbon containing material in the formation.

5077. The method of claim 5073, wherein the second stream comprises  $H_2$  from the formation and, further comprising providing such  $H_2$  to the ammonia synthesis process.

10 5078. The method of claim 5073, further comprising using the ammonia synthesis process to generate ammonia.

5079. The method of claim 5078, wherein fluids produced during pyrolysis of a hydrocarbon containing formation comprise ammonia and, further comprising adding at least a portion of such ammonia to the ammonia generated from the ammonia synthesis process.

15 5080. The method of claim 5078, wherein fluids produced during pyrolysis of a hydrocarbon formation are hydrotreated and at least some ammonia is produced during hydrotreating, and further comprising adding at least a portion of such ammonia to the ammonia generated from the ammonia synthesis process.

5081. The method of claim 5078, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea.

25 5082. The method of claim 5078, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea and, further comprising providing carbon dioxide from the formation to the urea synthesis process.

30

5083. The method of claim 5078, further comprising providing at least a portion of the ammonia to a urea synthesis process to produce urea and further comprising shifting at least a portion of carbon monoxide in the synthesis gas to carbon dioxide in a shift process, and further comprising providing at least a portion of the carbon dioxide from the shift process to the urea synthesis process.

5084. A method of treating a hydrocarbon containing permeable formation in situ, comprising:

providing heat from one or more heat sources to at least one portion of the permeable formation;

allowing the heat to transfer from the one or more heat sources to a selected mobilization section of the permeable formation such that the heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation;

controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected mobilization section of the permeable formation is less than about 150°C;

allowing the heat to transfer from the one or more heat sources to a selected pyrolyzation section of the permeable formation such that the heat from the one or more heat sources can pyrolyze at least some of the hydrocarbons within the selected pyrolyzation section of the permeable formation;

controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected pyrolyzation section of the permeable formation is less than about 375°C; and

producing a mixture from the permeable formation.

5085. The method of claim 5084, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation.

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5086. The method of claim 5084, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected pyrolyzation section of the permeable formation.

5087. The method of claim 5084, wherein the one or more heat sources comprise electrical heaters.

5088. The method of claim 5084, wherein the one or more heat sources comprise surface burners.

5089. The method of claim 5084, wherein the one or more heat sources comprise flameless distributed combustors.

5090. The method of claim 5084, wherein the one or more heat sources comprise natural distributed combustors.

5091. The method of claim 5084, further comprising disposing the one or more heat sources horizontally within the permeable formation.

5092. The method of claim 5084, further comprising controlling a pressure and a temperature within at least a majority of the permeable formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure.

5093. The method of claim 5084, further comprising controlling the heat such that an average heating rate of the selected pyrolyzation section is less than about 15 °C/day during pyrolysis.

5094. The method of claim 5084, wherein providing heat from the one or more heat sources to at least the portion of permeable formation comprises:

heating a selected volume ( $V$ ) of the hydrocarbon containing permeable formation from the one or more heat sources, wherein the formation has an average heat capacity( $C_v$ ), and wherein the heating pyrolyzes at least some hydrocarbons within the selected volume of the formation; and

5 wherein heating energy/day provided to the volume is equal to or less than  $P_{wr}$ , wherein  $P_{wr}$  is calculated by the equation:

$$P_{wr} = h * V * C_v * \rho_B$$

10 wherein  $P_{wr}$  is the heating energy/day,  $h$  is an average heating rate of the formation,  $\rho_B$  is formation bulk density, and wherein the heating rate is less than about 10 °C/day.

5095. The method of claim 5084, wherein allowing the heat to transfer from the one or more heat sources to the selected mobilization section and/or the selected pyrolyzation section comprises transferring heat substantially by conduction.

5096. The method of claim 5084, wherein producing the mixture from the permeable formation further comprises producing mixture having an API gravity of at least about 25°.

20 5097. The method of claim 5084, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 0.5 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is nitrogen.

25 5098. The method of claim 5084, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 7 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is oxygen.

30 5099. The method of claim 5084, wherein the produced mixture comprises sulfur, and wherein less than about 5 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is sulfur.



5100. The method of claim 5084, further comprising controlling a pressure within at least a majority of the permeable formation, wherein the controlled pressure is at least about 2 bar absolute.

5 5101. The method of claim 5084, further comprising altering a pressure within the permeable formation to inhibit production of hydrocarbons from the permeable formation having carbon numbers greater than about 25.

5102. The method of claim 5084, further comprising:

10 providing hydrogen ( $H_2$ ) to the heated section to hydrogenate hydrocarbons within the section; and

heating a portion of the section with heat from hydrogenation.

5103. The method of claim 5084, wherein the produced mixture comprises condensable hydrocarbons and hydrogen, the method further comprising hydrogenating a portion of the produced condensable hydrocarbons with at least a portion of the produced hydrogen.

5104. The method of claim 5084, wherein producing the mixture from the permeable formation further comprises producing the mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein at least about 4 heat sources are disposed in the permeable formation for each production well.

5105. The method of claim 5084, wherein producing the mixture from the permeable formation further comprises producing the mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein the production well is disposed substantially horizontally within the permeable formation.

5106. The method of claim 5084, further comprising separating the mixture into a gas stream and a liquid stream.

5107. The method of claim 5084, further comprising separating the mixture into a gas stream and a liquid stream and separating the liquid stream into an aqueous stream and a non-aqueous stream.

5108. The method of claim 5084, wherein the mixture is produced from a production well, the method further comprising heating a wellbore of the production well to inhibit condensation of the mixture within the wellbore.

5109. The method of claim 5084, wherein the mixture is produced from a production well, wherein a wellbore of the production well comprises a heater element configured to heat the permeable formation adjacent to the wellbore, and further comprising heating the permeable formation with the heater element to produce the mixture, wherein the mixture comprises non-condensable hydrocarbons and H<sub>2</sub>.

5110. The method of claim 5084, wherein a minimum mobilization temperature is about 75 °C.

5111. The method of claim 5084, wherein a minimum pyrolysis temperature is about 270 °C.

5112. The method of claim 5084, further comprising maintaining the pressure within the permeable formation above about 2 bar absolute to inhibit production of fluids having carbon numbers above 25.

5113. The method of claim 5084, further comprising controlling pressure within the permeable formation in a range from about atmospheric pressure to about 100 bar absolute, as measured at a wellhead of a production well, to control an amount of condensable fluids within the mixture, wherein the pressure is reduced to increase production of condensable fluids, and wherein the pressure is increased to increase production of non-condensable fluids.

5114. The method of claim 5084, further comprising controlling pressure within the permeable formation in a range from about atmospheric pressure to about 100 bar absolute, as measured at a wellhead of a production well, to control an API gravity of condensable fluids within the mixture, wherein the pressure is reduced to decrease the API gravity, and wherein the pressure is increased to reduce the API gravity.

5115. The method of claim 5084, wherein mobilizing the hydrocarbons within the selected mobilization section comprises reducing a viscosity of the hydrocarbons.

5116. The method of claim 5084, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation.

5117. The method of claim 5084, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, and wherein the gas comprises carbon dioxide.

5118. The method of claim 5084, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, and wherein the gas comprises nitrogen.

5119. The method of claim 5084, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, the method further comprising

controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled.

5120. The method of claim 5084, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, the method further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled, wherein the pressure of the provided gas is above about 2 bar absolute.

5121. The method of claim 5084, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, the method further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled, wherein the pressure of the provided gas is below about 70 bar absolute.

5122. A method of treating a hydrocarbon containing permeable formation in situ, comprising:

providing heat from one or more heat sources to at least one portion of the permeable formation;

allowing the heat to transfer from the one or more heat sources to a selected mobilization section of the permeable formation such that the heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation;

controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected mobilization section of the permeable formation is less than about 150°C;

allowing the heat to transfer from the one or more heat sources to a selected pyrolyzation section of the permeable formation such that the heat from the one or more heat sources can pyrolyze at least some of the hydrocarbons within the selected pyrolyzation section of the permeable formation;

5 controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected pyrolyzation section of the permeable formation is less than about 375°C;

allowing at least some of the mobilized hydrocarbons to flow from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation; and

10 producing a mixture from the permeable formation.

5123. The method of claim 5122, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation.

5124. The method of claim 5122, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from the one or more heat sources can pyrolyze at least some of the hydrocarbons within the selected pyrolyzation section of the permeable formation.

5125. The method of claim 5122, wherein the one or more heat sources comprise electrical heaters.

5126. The method of claim 5122, wherein the one or more heat sources comprise surface burners.

5127. The method of claim 5122, wherein the one or more heat sources comprise flameless distributed combustors.

5128. The method of claim 5122, wherein the one or more heat sources comprise natural distributed combustors.

5129. The method of claim 5122, further comprising disposing the one or more heat sources horizontally within the permeable formation.

5130. The method of claim 5122, further comprising controlling a pressure and a temperature within at least a majority of the permeable formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure.

5131. The method of claim 5122, further comprising controlling the heat such that an average heating rate of the selected pyrolyzation section is less than about 15 °C/day during pyrolysis.

5132. The method of claim 5122, wherein providing heat from the one or more heat sources to at least the portion of permeable formation comprises:

heating a selected volume ( $V$ ) of the hydrocarbon containing permeable formation from the one or more heat sources, wherein the formation has an average heat capacity ( $C_v$ ), and wherein the heating pyrolyzes at least some hydrocarbons within the selected volume of the formation; and

wherein heating energy/day provided to the volume is equal to or less than  $P_{wr}$ , wherein  $P_{wr}$  is calculated by the equation:

$$P_{wr} = h * V * C_v * \rho_B$$

wherein  $P_{wr}$  is the heating energy/day,  $h$  is an average heating rate of the formation,  $\rho_B$  is formation bulk density, and wherein the heating rate is less than about 10 °C/day.

5133. The method of claim 5122, wherein allowing the heat to transfer from the one or more heat sources to the selected mobilization section and/or the selected pyrolyzation section comprises transferring heat substantially by conduction.

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5134. The method of claim 5122, wherein producing the mixture from the permeable formation further comprises producing a mixture having an API gravity of at least about 25°.

5135. The method of claim 5122, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 0.5 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is nitrogen.

5136. The method of claim 5122, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 7 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is oxygen.

5137. The method of claim 5122, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 5 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is sulfur.

5138. The method of claim 5122, further comprising controlling a pressure within at least a majority of the permeable formation, wherein the controlled pressure is at least about 2 bar absolute.

5139. The method of claim 5122, further comprising altering a pressure within the permeable formation to inhibit production of hydrocarbons from the permeable formation having carbon numbers greater than about 25.

5140. The method of claim 5122, further comprising:  
providing hydrogen (H<sub>2</sub>) to the heated section to hydrogenate hydrocarbons within the section; and  
heating a portion of the section with heat from hydrogenation.

5141. The method of claim 5122, wherein the produced mixture comprises condensable hydrocarbons and hydrogen, the method further comprising hydrogenating a portion of the produced condensable hydrocarbons with at least a portion of the produced hydrogen.

5 5142. The method of claim 5122, wherein producing the mixture from the permeable formation further comprises producing mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein at least about 4 heat sources are disposed in the permeable formation for each production well.

10 5143. The method of claim 5122, wherein producing the mixture from the permeable formation further comprises producing mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein the production well is disposed substantially horizontally within the permeable formation.

15 5144. The method of claim 5122, further comprising separating the mixture into a gas stream and a liquid stream.

20 5145. The method of claim 5122, further comprising separating the mixture into a gas stream and a liquid stream and separating the liquid stream into an aqueous stream and a non-aqueous stream.

25 5146. The method of claim 5122, wherein the mixture is produced from a production well, the method further comprising heating a wellbore of the production well to inhibit condensation of the mixture within the wellbore.

30 5147. The method of claim 5122, wherein the mixture is produced from a production well, wherein a wellbore of the production well comprises a heater element configured to heat the permeable formation adjacent to the wellbore, and further comprising heating the

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permeable formation with the heater element to produce the mixture, wherein the mixture comprises non-condensable hydrocarbons and H<sub>2</sub>.

5148. The method of claim 5122, wherein a minimum mobilization temperature is about 75 °C.

5149. The method of claim 5122, wherein a minimum pyrolysis temperature is about 270 °C.

5150. The method of claim 5122, further comprising maintaining the pressure within the permeable formation above about 2 bar absolute to inhibit production of fluids having carbon numbers above 25.

5151. The method of claim 5122, further comprising controlling pressure within the permeable formation in a range from about atmospheric pressure to about 100 bar absolute, as measured at a wellhead of a production well, to control an amount of condensable fluids within the mixture, wherein the pressure is reduced to increase production of condensable fluids, and wherein the pressure is increased to increase production of non-condensable fluids.

5152. The method of claim 5122, further comprising controlling pressure within the permeable formation in a range from about atmospheric pressure to about 100 bar absolute, as measured at a wellhead of a production well, to control an API gravity of condensable fluids within the mixture, wherein the pressure is reduced to decrease the API gravity, and wherein the pressure is increased to reduce the API gravity.

5153. The method of claim 5122, wherein mobilizing the hydrocarbons within the selected mobilization section comprises reducing a viscosity of the hydrocarbons.

5154. The method of claim 5122, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized

hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation.

5155. The method of claim 5122, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, and wherein the gas comprises carbon dioxide.

5156. The method of claim 5122, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, and wherein the gas comprises nitrogen.

5157. The method of claim 5122, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, the method further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled.

5158. The method of claim 5122, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, the method further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled, wherein the pressure of the provided gas is above about 2 bar absolute.

5159. The method of claim 5122, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, the method further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled, wherein the pressure of the provided gas is below about 100 bar absolute.

5160. A method of treating a hydrocarbon containing permeable formation in situ, comprising:

providing heat from one or more heat sources to at least one portion of the permeable formation;

allowing the heat to transfer from the one or more heat sources to a selected mobilization section of the permeable formation such that the heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation;

controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected mobilization section of the permeable formation is less than about 150°C;

allowing the heat to transfer from the one or more heat sources to a selected pyrolyzation section of the permeable formation such that the heat from the one or more heat sources can pyrolyze at least some of the hydrocarbons within the selected pyrolyzation section of the permeable formation;

controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected pyrolyzation section of the permeable formation is less than about 375°C;

allowing at least some of the mobilized hydrocarbons to flow from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation;

providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of

the permeable formation to the selected pyrolyzation section of the permeable formation;  
and

producing a mixture from the permeable formation.

5 5161. The method of claim 5160, wherein the one or more heat sources comprise at least two heat sources, and wherein the heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation.

10 5162. The method of claim 5160, wherein the one or more heat sources comprise at least two heat sources, and wherein the heat from the one or more heat sources can pyrolyze at least some of the hydrocarbons within the selected pyrolyzation section of the permeable formation.

15 5163. The method of claim 5160, wherein the one or more heat sources comprise electrical heaters.

5164. The method of claim 5160, wherein the one or more heat sources comprise surface burners.

20 5165. The method of claim 5160, wherein the one or more heat sources comprise flameless distributed combustors.

25 5166. The method of claim 5160, wherein the one or more heat sources comprise natural distributed combustors.

5167. The method of claim 5160, further comprising disposing the one or more heat sources horizontally within the permeable formation.

30 5168. The method of claim 5160, further comprising controlling a pressure and a temperature within at least a majority of the permeable formation, wherein the pressure is

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controlled as a function of temperature, or the temperature is controlled as a function of pressure.

5169. The method of claim 5160, further comprising controlling the heat such that an average heating rate of the selected pyrolyzation section is less than about 15 °C/day during pyrolysis.

5170. The method of claim 5160, wherein providing heat from the one or more heat sources to at least the portion of permeable formation comprises:

heating a selected volume ( $V$ ) of the hydrocarbon containing permeable formation from the one or more heat sources, wherein the formation has an average heat capacity( $C_v$ ), and wherein the heating pyrolyzes at least some hydrocarbons within the selected volume of the formation; and

wherein heating energy/day provided to the volume is equal to or less than  $P_{wr}$ , wherein  $P_{wr}$  is calculated by the equation:

$$P_{wr} = h * V * C_v * \rho_B$$

wherein  $P_{wr}$  is the heating energy/day,  $h$  is an average heating rate of the formation,  $\rho_B$  is formation bulk density, and wherein the heating rate is less than about 10 °C/day.

5171. The method of claim 5160, wherein allowing the heat to transfer from the one or more heat sources to the selected mobilization section and/or the selected pyrolyzation section comprises transferring heat substantially by conduction.

5172. The method of claim 5160, wherein producing mixture from the permeable formation further comprises producing mixture having an API gravity of at least about 25°.

5173. The method of claim 5160, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 0.5 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is nitrogen.

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5174. The method of claim 5160, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 7 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is oxygen.

5175. The method of claim 5160, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 5 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is sulfur.

5176. The method of claim 5160, further comprising controlling a pressure within at least a majority of the permeable formation, wherein the controlled pressure is at least about 2 bar absolute.

5177. The method of claim 5160, further comprising altering a pressure within the permeable formation to inhibit production of hydrocarbons from the permeable formation having carbon numbers greater than about 25.

5178. The method of claim 5160, further comprising:  
providing hydrogen ( $H_2$ ) to the heated section to hydrogenate hydrocarbons within the section; and  
heating a portion of the section with heat from hydrogenation.

5179. The method of claim 5160, wherein the produced mixture comprises condensable hydrocarbons and hydrogen, the method further comprising hydrogenating a portion of the produced condensable hydrocarbons with at least a portion of the produced hydrogen.

5180. The method of claim 5160, wherein producing the mixture from the permeable formation further comprises producing the mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein at least about 4 heat sources are disposed in the permeable formation for each production well.

5181. ~~The method of claim 5160, wherein producing the mixture from the permeable formation further comprises producing the mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein the production well is disposed substantially horizontally within the permeable formation.~~

5182. The method of claim 5160, further comprising separating the mixture into a gas stream and a liquid stream.

5183. The method of claim 5160, further comprising separating the mixture into a gas stream and a liquid stream and separating the liquid stream into an aqueous stream and a non-aqueous stream.

5184. The method of claim 5160, wherein the mixture is produced from a production well, the method further comprising heating a wellbore of the production well to inhibit condensation of the mixture within the wellbore.

5185. The method of claim 5160, wherein the mixture is produced from a production well, wherein a wellbore of the production well comprises a heater element configured to heat the permeable formation adjacent to the wellbore, and further comprising heating the permeable formation with the heater element to produce the mixture, wherein the mixture comprise non-condensable hydrocarbons and  $H_2$ .

5186. The method of claim 5160, wherein a minimum mobilization temperature is about  $75^\circ C$ .

5187. The method of claim 5160, wherein a minimum pyrolysis temperature is about  $270^\circ C$ .

5188. The method of claim 5160, further comprising maintaining the pressure within the permeable formation above about 2 bar absolute to inhibit production of fluids having carbon numbers above 25.

5 5189. The method of claim 5160, further comprising controlling pressure within the permeable formation in a range from about atmospheric pressure to about 100 bar absolute, as measured at a wellhead of a production well, to control an amount of condensable fluids within the mixture, wherein the pressure is reduced to increase production of condensable fluids, and wherein the pressure is increased to increase  
10 production of non-condensable fluids.

5190. The method of claim 5160, further comprising controlling pressure within the permeable formation in a range from about atmospheric pressure to about 100 bar absolute, as measured at a wellhead of a production well, to control an API gravity of  
15 condensable fluids within the mixture, wherein the pressure is reduced to decrease the API gravity, and wherein the pressure is increased to reduce the API gravity.

5191. The method of claim 5160, wherein mobilizing the hydrocarbons within the selected mobilization section comprises reducing a viscosity of the hydrocarbons.  
20

5192. The method of claim 5160, wherein the provided gas comprises carbon dioxide.

5193. The method of claim 5160, wherein the provided gas comprises nitrogen.

25 5194. The method of claim 5160, further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled.

5195. The method of claim 5160, further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled, wherein the  
30 pressure of the provided gas is above about 2 bar absolute.



5196. The method of claim 5160, further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled, wherein the pressure of the provided gas is below about 100 bar absolute.

5 5197. A method of treating a hydrocarbon containing permeable formation in situ, comprising:

providing heat from one or more heat sources to at least one portion of the permeable formation;

10 allowing the heat to transfer from the one or more heat sources to a selected mobilization section of the permeable formation such that the heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation;

15 controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected mobilization section of the permeable formation is less than about 150°C;

allowing the heat to transfer from the one or more heat sources to a selected pyrolyzation section of the permeable formation such that the heat from the one or more heat sources can pyrolyze at least some of the hydrocarbons within the selected pyrolyzation section of the permeable formation;

20 controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected pyrolyzation section of the permeable formation is less than about 375°C;

25 allowing at least some of the mobilized hydrocarbons to flow from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation;

providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation;

30 controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled; and

producing a mixture from the permeable formation.

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5198. The method of claim 5197, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation.

5199. The method of claim 5197, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from the one or more heat sources can pyrolyze at least some of the hydrocarbons within the selected pyrolyzation section of the permeable formation.

5200. The method of claim 5197, wherein the one or more heat sources comprise electrical heaters.

5201. The method of claim 5197, wherein the one or more heat sources comprise surface burners.

5202. The method of claim 5197, wherein the one or more heat sources comprise flameless distributed combustors.

5203. The method of claim 5197, wherein the one or more heat sources comprise natural distributed combustors.

5204. The method of claim 5197, further comprising disposing the one or more heat sources horizontally within the permeable formation.

5205. The method of claim 5197, further comprising controlling a pressure and a temperature within at least a majority of the permeable formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure.

5206. The method of claim 5197, further comprising controlling the heat such that an average heating rate of the selected pyrolyzation section is less than about 15 °C/day during pyrolysis.

5 5207. The method of claim 5197, wherein providing heat from the one or more heat sources to at least the portion of permeable formation comprises:

heating a selected volume ( $V$ ) of the hydrocarbon containing permeable formation from the one or more heat sources, wherein the formation has an average heat capacity( $C_v$ ), and wherein the heating pyrolyzes at least some hydrocarbons within the selected volume of the formation; and

10 wherein heating energy/day provided to the volume is equal to or less than  $P_{wr}$ , wherein  $P_{wr}$  is calculated by the equation:

$$P_{wr} = h * V * C_v * \rho_B$$

15 wherein  $P_{wr}$  is the heating energy/day,  $h$  is an average heating rate of the formation,  $\rho_B$  is formation bulk density, and wherein the heating rate is less than about 10 °C/day.

20 5208. The method of claim 5197, wherein allowing the heat to transfer from the one or more heat sources to the selected mobilization section and/or the selected pyrolyzation section comprises transferring heat substantially by conduction.

25 5209. The method of claim 5197, wherein producing the mixture from the permeable formation further comprises producing mixture having an API gravity of at least about 25°.

5210. The method of claim 5197, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 0.5 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is nitrogen.

5211. The method of claim 5197, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 7 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is oxygen.

5 5212. The method of claim 5197, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 5 % by weight, of the condensable hydrocarbons, when calculated on an atomic basis, is sulfur.

10 5213. The method of claim 5197, further comprising controlling a pressure within at least a majority of the permeable formation, wherein the controlled pressure is at least about 2 bar absolute.

15 5214. The method of claim 5197, further comprising altering a pressure within the permeable formation to inhibit production of hydrocarbons from the permeable formation having carbon numbers greater than about 25.

20 5215. The method of claim 5197, further comprising:  
providing hydrogen ( $H_2$ ) to the heated section to hydrogenate hydrocarbons within the section; and  
heating a portion of the section with heat from hydrogenation.

25 5216. The method of claim 5197, wherein the produced mixture comprises condensable hydrocarbons and hydrogen, the method further comprising hydrogenating a portion of the produced condensable hydrocarbons with at least a portion of the produced hydrogen.

30 5217. The method of claim 5197, wherein producing the mixture from the permeable formation further comprises producing the mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein at least about 4 heat sources are disposed in the permeable formation for each production well.

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5218. The method of claim 5197, wherein producing the mixture from the permeable formation further comprises producing the mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein the production well is disposed substantially horizontally within the permeable formation.

5219. The method of claim 5197, further comprising separating the mixture into a gas stream and a liquid stream.

5220. The method of claim 5197, further comprising separating the mixture into a gas stream and a liquid stream and separating the liquid stream into an aqueous stream and a non-aqueous stream.

5221. The method of claim 5197, wherein the mixture is produced from a production well, the method further comprising heating a wellbore of the production well to inhibit condensation of the mixture within the wellbore.

5222. The method of claim 5197, wherein the mixture is produced from a production well, wherein a wellbore of the production well comprises a heater element configured to heat the permeable formation adjacent to the wellbore, and further comprising heating the permeable formation with the heater element to produce the mixture, wherein the mixture comprises non-condensable hydrocarbons and  $H_2$ .

5223. The method of claim 5197, wherein a minimum mobilization temperature is about 75 °C.

5224. The method of claim 5197, wherein a minimum pyrolysis temperature is about 270 °C.

5225. The method of claim 5197, further comprising maintaining the pressure within the permeable formation above about 2 bar absolute to inhibit production of fluids having carbon numbers above 25.

5 5226. The method of claim 5197, further comprising controlling pressure within the permeable formation in a range from about atmospheric pressure to about 100 bar absolute, as measured at a wellhead of a production well, to control an amount of condensable fluids within the mixture, wherein the pressure is reduced to increase production of condensable fluids, and wherein the pressure is increased to increase  
10 production of non-condensable fluids.

5227. The method of claim 5197, further comprising controlling pressure within the permeable formation in a range from about atmospheric pressure to about 100 bar absolute, as measured at a wellhead of a production well, to control an API gravity of  
15 condensable fluids within the mixture, wherein the pressure is reduced to decrease the API gravity, and wherein the pressure is increased to reduce the API gravity.

5228. The method of claim 5197, wherein mobilizing the hydrocarbons within the selected mobilization section comprises reducing a viscosity of the hydrocarbons.  
20

5229. The method of claim 5197, wherein the provided gas comprises carbon dioxide.

5230. The method of claim 5197, wherein the provided gas comprises nitrogen.

25 5231. The method of claim 5197, wherein the pressure of the provided gas is above about 2 bar absolute.

5232. The method of claim 5197, wherein the pressure of the provided gas is below about 70 bar absolute.  
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5233. ~~A method of treating a hydrocarbon containing permeable formation in situ,~~  
comprising:

providing heat from one or more heat sources to at least one portion of the permeable formation;

5 allowing the heat to transfer from the one or more heat sources to a selected mobilization section of the permeable formation such that the heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation;

10 controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected mobilization section of the permeable formation is less than about 150°C;

15 allowing the heat to transfer from the one or more heat sources to a selected pyrolyzation section of the permeable formation such that the heat from the one or more heat sources can pyrolyze at least some of the hydrocarbons within the selected pyrolyzation section of the permeable formation;

controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected pyrolyzation section of the permeable formation is less than about 375°C; and

20 producing a mixture from the permeable formation in a production well, wherein the production well is disposed substantially horizontally within the permeable formation.

5234. The method of claim 5233, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation.

5235. The method of claim 5233, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from the one or more heat sources can pyrolyze at least some of the hydrocarbons within the selected pyrolyzation section of the permeable formation.

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5236. The method of claim 5233, wherein the one or more heat sources comprise electrical heaters.

5237. The method of claim 5233, wherein the one or more heat sources comprise surface burners.

5238. The method of claim 5233, wherein the one or more heat sources comprise flameless distributed combustors.

5239. The method of claim 5233, wherein the one or more heat sources comprise natural distributed combustors.

5240. The method of claim 5233, further comprising disposing the one or more heat sources horizontally within the permeable formation.

5241. The method of claim 5233, further comprising controlling a pressure and a temperature within at least a majority of the permeable formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure.

5242. The method of claim 5233, further comprising controlling the heat such that an average heating rate of the selected pyrolyzation section is less than about 15 °C/day during pyrolysis.

5243. The method of claim 5233, wherein providing heat from the one or more heat sources to at least the portion of permeable formation comprises:

heating a selected volume ( $V$ ) of the hydrocarbon containing permeable formation from the one or more heat sources, wherein the formation has an average heat capacity( $C_v$ ), and wherein the heating pyrolyzes at least some hydrocarbons within the selected volume of the formation; and



wherein heating energy/day provided to the volume is equal to or less than  $P_{wr}$ ,  
wherein  $P_{wr}$  is calculated by the equation:

$$P_{wr} = h * V * C_v * \rho_B$$

wherein  $P_{wr}$  is the heating energy/day,  $h$  is an average heating rate of the  
5 formation,  $\rho_B$  is formation bulk density, and wherein the heating rate is less than about 10  
°C/day.

5244. The method of claim 5233, wherein allowing the heat to transfer from the one or  
10 more heat sources to the selected mobilization section and/or the selected pyrolyzation  
section comprises transferring heat substantially by conduction.

5245. The method of claim 5233, wherein producing mixture from the permeable  
15 formation further comprises producing mixture having an API gravity of at least about  
25°.

5246. The method of claim 5233, wherein the produced mixture comprises condensable  
20 hydrocarbons, and wherein less than about 0.5 % by weight, of the condensable  
hydrocarbons, when calculated on an atomic basis, is nitrogen.

5247. The method of claim 5233, wherein the produced mixture comprises condensable  
25 hydrocarbons, and wherein less than about 7 % by weight, of the condensable  
hydrocarbons, when calculated on an atomic basis, is oxygen.

5248. The method of claim 5233, wherein the produced mixture comprises condensable  
30 hydrocarbons, and wherein less than about 5 % by weight, of the condensable  
hydrocarbons, when calculated on an atomic basis, is sulfur.

5249. The method of claim 5233, further comprising controlling a pressure within at  
least a majority of the permeable formation, wherein the controlled pressure is at least  
about 2 bar absolute.

5250. The method of claim 5233, further comprising altering a pressure within the permeable formation to inhibit production of hydrocarbons from the permeable formation having carbon numbers greater than about 25.

5 5251. The method of claim 5233, further comprising:

providing hydrogen ( $H_2$ ) to the heated section to hydrogenate hydrocarbons within the section; and

heating a portion of the section with heat from hydrogenation.

10 5252. The method of claim 5233, wherein the produced mixture comprises condensable hydrocarbons and hydrogen, the method further comprising hydrogenating a portion of the produced condensable hydrocarbons with at least a portion of the produced hydrogen.

15 5253. The method of claim 5233, wherein producing the mixture from the permeable formation further comprises producing the mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein at least about 4 heat sources are disposed in the permeable formation for each production well.

20 5254. The method of claim 5233, further comprising separating the mixture into a gas stream and a liquid stream.

25 5255. The method of claim 5233, further comprising separating the mixture into a gas stream and a liquid stream and separating the liquid stream into an aqueous stream and a non-aqueous stream.

30 5256. The method of claim 5233, wherein the mixture is produced from a production well, the method further comprising heating a wellbore of the production well to inhibit condensation of the mixture within the wellbore.

5257. The method of claim 5233, wherein the mixture is produced from a production well, wherein a wellbore of the production well comprises a heater element configured to heat the permeable formation adjacent to the wellbore, and further comprising heating the permeable formation with the heater element to produce the mixture, wherein the mixture comprises non-condensable hydrocarbons and H<sub>2</sub>.

5258. The method of claim 5233, wherein a minimum mobilization temperature is about 75 °C.

5259. The method of claim 5233, wherein a minimum pyrolysis temperature is about 270 °C.

5260. The method of claim 5233, further comprising maintaining the pressure within the permeable formation above about 2 bar absolute to inhibit production of fluids having carbon numbers above 25.

5261. The method of claim 5233, further comprising controlling pressure within the permeable formation in a range from about atmospheric pressure to about 100 bar absolute, as measured at a wellhead of a production well, to control an amount of condensable fluids within the mixture, wherein the pressure is reduced to increase production of condensable fluids, and wherein the pressure is increased to increase production of non-condensable fluids.

5262. The method of claim 5233, further comprising controlling pressure within the permeable formation in a range from about atmospheric pressure to about 100 bar absolute, as measured at a wellhead of a production well, to control an API gravity of condensable fluids within the mixture, wherein the pressure is reduced to decrease the API gravity, and wherein the pressure is increased to reduce the API gravity.

5263. The method of claim 5233, wherein mobilizing the hydrocarbons within the selected mobilization section comprises reducing a viscosity of the hydrocarbons.

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5 5264. The method of claim 5233, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation.

10 5265. The method of claim 5233, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, and wherein the gas comprises carbon dioxide.

15 5266. The method of claim 5233, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, and wherein the gas comprises nitrogen.

20 5267. The method of claim 5233, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, the method further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled.

25 5268. The method of claim 5233, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, the method further comprising  
30 controlling a pressure of the provided gas such that the flow of the mobilized

hydrocarbons is controlled, wherein the pressure of the provided gas is above about 2 bar absolute.

5269. The method of claim 5233, further comprising providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons from the selected mobilization section of the permeable formation to the selected pyrolyzation section of the permeable formation, the method further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled, wherein the pressure of the provided gas is below about 70 bar absolute.

5270. A method of treating a hydrocarbon containing permeable formation in situ, comprising:

providing heat from one or more heat sources to at least one portion of the permeable formation;

allowing the heat to transfer from the one or more heat sources to a selected mobilization section of the permeable formation such that the heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation;

controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected mobilization section of the permeable formation is less than about 150°C;

providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons within the permeable formation; and producing a mixture from the permeable formation.

5271. The method of claim 5270, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation.

5272. The method of claim 5270, wherein the one or more heat sources comprise electrical heaters.

5 5273. The method of claim 5270, wherein the one or more heat sources comprise surface burners.

5274. The method of claim 5270, wherein the one or more heat sources comprise flameless distributed combustors.

10 5275. The method of claim 5270, wherein the one or more heat sources comprise natural distributed combustors.

5276. The method of claim 5270, further comprising disposing the one or more heat sources horizontally within the permeable formation.

15 5277. The method of claim 5270, further comprising controlling a pressure and a temperature within at least a majority of the permeable formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure.

20 5278. The method of claim 5270, wherein providing heat from the one or more heat sources to at least the portion of permeable formation comprises:

25 heating a selected volume ( $V$ ) of the hydrocarbon containing permeable formation from the one or more heat sources, wherein the formation has an average heat capacity( $C_v$ ), and wherein the heating pyrolyzes at least some hydrocarbons within the selected volume of the formation; and

wherein heating energy/day provided to the volume is equal to or less than  $P_{wr}$ , wherein  $P_{wr}$  is calculated by the equation:

$$P_{wr} = h * V * C_v * \rho_B$$

wherein  $P_{wr}$  is the heating energy/day,  $h$  is an average heating rate of the formation,  $\rho_B$  is formation bulk density, and wherein the heating rate is less than about 10 °C/day.

5 5279. The method of claim 5270, wherein allowing the heat to transfer from the one or more heat sources to the selected mobilization section comprises transferring heat substantially by conduction.

10 5280. The method of claim 5270, further comprising controlling a pressure within at least a majority of the permeable formation, wherein the controlled pressure is at least about 2 bar absolute.

15 5281. The method of claim 5270, wherein producing the mixture from the permeable formation further comprises producing the mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein at least about 4 heat sources are disposed in the permeable formation for each production well.

20 5282. The method of claim 5270, wherein producing the mixture from the permeable formation further comprises producing the mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein the production well is disposed substantially horizontally within the permeable formation.

25 5283. The method of claim 5270, further comprising separating the mixture into a gas stream and a liquid stream.

30 5284. The method of claim 5270, further comprising separating the mixture into a gas stream and a liquid stream and separating the liquid stream into an aqueous stream and a non-aqueous stream.

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5285. The method of claim 5270, wherein the mixture is produced from a production well, the method further comprising heating a wellbore of the production well to inhibit condensation of the mixture within the wellbore.

5 5286. The method of claim 5270, wherein the mixture is produced from a production well, wherein a wellbore of the production well comprises a heater element configured to heat the permeable formation adjacent to the wellbore, and further comprising heating the permeable formation with the heater element to produce the mixture, wherein the mixture comprise non-condensable hydrocarbons and H<sub>2</sub>.

10 5287. The method of claim 5270, wherein a minimum mobilization temperature is about 75 °C.

15 5288. The method of claim 5270, wherein mobilizing the hydrocarbons within the selected mobilization section comprises reducing a viscosity of the hydrocarbons.

5289. The method of claim 5270, wherein the provided gas comprises carbon dioxide.

5290. The method of claim 5270, wherein the provided gas comprises nitrogen.

20 5291. The method of claim 5270, further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled.

25 5292. The method of claim 5270, further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled, wherein the pressure of the provided gas is above about 2 bar absolute.

30 5293. The method of claim 5270, further comprising controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled, wherein the pressure of the provided gas is below about 70 bar absolute.



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5294. A method of treating a hydrocarbon containing permeable formation in situ, comprising:

providing heat from one or more heat sources to at least one portion of the permeable formation;

5 allowing the heat to transfer from the one or more heat sources to a selected mobilization section of the permeable formation such that the heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation;

10 controlling the heat from the one or more heat sources such that an average temperature within at least a majority of the selected mobilization section of the permeable formation is less than about 150°C;

providing a gas to the permeable formation, wherein the gas is configured to increase a flow of the mobilized hydrocarbons within the permeable formation;

15 controlling a pressure of the provided gas such that the flow of the mobilized hydrocarbons is controlled; and

producing a mixture from the permeable formation.

20 5295. The method of claim 5294, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from the one or more heat sources can mobilize at least some of the hydrocarbons within the selected mobilization section of the permeable formation.

25 5296. The method of claim 5294, wherein the one or more heat sources comprise electrical heaters.

5297. The method of claim 5294, wherein the one or more heat sources comprise surface burners.

30 5298. The method of claim 5294, wherein the one or more heat sources comprise flameless distributed combustors.

5299. The method of claim 5294, wherein the one or more heat sources comprise natural distributed combustors.

5300. The method of claim 5294, further comprising disposing the one or more heat sources horizontally within the permeable formation.

5301. The method of claim 5294, further comprising controlling a pressure and a temperature within at least a majority of the permeable formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure.

5302. The method of claim 5294, wherein providing heat from the one or more heat sources to at least the portion of permeable formation comprises:

heating a selected volume ( $V$ ) of the hydrocarbon containing permeable formation from the one or more heat sources, wherein the formation has an average heat capacity ( $C_v$ ), and wherein the heating pyrolyzes at least some hydrocarbons within the selected volume of the formation; and

wherein heating energy/day provided to the volume is equal to or less than  $P_{wr}$ , wherein  $P_{wr}$  is calculated by the equation:

$$P_{wr} = h * V * C_v * \rho_B$$

wherein  $P_{wr}$  is the heating energy/day,  $h$  is an average heating rate of the formation,  $\rho_B$  is formation bulk density, and wherein the heating rate is less than about 10 °C/day.

5303. The method of claim 5294, wherein allowing the heat to transfer from the one or more heat sources to the selected mobilization section comprises transferring heat substantially by conduction.

5304. The method of claim 5294, further comprising controlling a pressure within at least a majority of the permeable formation, wherein the controlled pressure is at least about 2 bar absolute.

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5305. The method of claim 5294, wherein producing the mixture from the permeable formation further comprises producing the mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein at least about 4 heat sources are disposed in the permeable formation for each production well.

5306. The method of claim 5294, wherein producing the mixture from the permeable formation further comprises producing the mixture in a production well, wherein the heating is controlled such that the mixture can be produced from the permeable formation, and wherein the production well is disposed substantially horizontally within the permeable formation.

5307. The method of claim 5294, further comprising separating the mixture into a gas stream and a liquid stream.

5308. The method of claim 5294, further comprising separating the mixture into a gas stream and a liquid stream and separating the liquid stream into an aqueous stream and a non-aqueous stream.

5309. The method of claim 5294, wherein the mixture is produced from a production well, the method further comprising heating a wellbore of the production well to inhibit condensation of the mixture within the wellbore.

5310. The method of claim 5294, wherein the mixture is produced from a production well, wherein a wellbore of the production well comprises a heater element configured to heat the permeable formation adjacent to the wellbore, and further comprising heating the permeable formation with the heater element to produce the mixture, wherein the mixture comprise non-condensable hydrocarbons and  $H_2$ .

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5311. The method of claim 5294, wherein a minimum mobilization temperature is about 75 °C.

5 5312. The method of claim 5294, wherein mobilizing the hydrocarbons within the selected mobilization section comprises reducing a viscosity of the hydrocarbons.

5313. The method of claim 5294, wherein the provided gas comprises carbon dioxide.

10 5314. The method of claim 5294, wherein the provided gas comprises nitrogen.

5315. The method of claim 5294, wherein the pressure of the provided gas is above about 2 bar absolute.

15 5316. The method of claim 5294, wherein the pressure of the provided gas is below about 70 bar absolute.

5317. A method for treating hydrocarbons in at least a portion of a hydrocarbon containing formation, wherein the portion has an average permeability of less than about 10 millidarcy, comprising:

20 providing heat from one or more heat sources to the formation;  
allowing the heat to transfer from one or more of the heat sources to a selected section of the formation such that heat from the heat sources pyrolyzes at least some hydrocarbons within the selected section, and wherein heat from the heat sources increases the permeability of at least a portion of the selected section; and  
25 producing a mixture comprising hydrocarbons from the formation.

5318. The method of claim 5317, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from at least the two heat sources pyrolyzes at least some hydrocarbons within the selected section of the  
30 formation, and wherein superposition of heat from at least the two heat sources increases the permeability of at least the portion of the selected section.

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5319. The method of claim 5317, further comprising allowing heat to transfer from at least one of the heat sources to the selected section to create thermal fractures in the formation wherein the thermal fractures substantially increase the permeability of the selected section.

5320. The method of claim 5317, wherein the heat is provided such that an average temperature in the selected section ranges from approximately about 270 °C to about 375 °C.

5321. The method of claim 5317, wherein at least one of the heat sources comprises an electrical heater located in the formation.

5322. The method of claim 5317, wherein at least one of the heat sources is located in a heater well, and wherein at least one of the heater wells comprises a conduit located in the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

5323. The method of claim 5317, wherein at least some of the heat sources are arranged in a triangular pattern.

5324. The method of claim 5317, further comprising:  
monitoring a composition of the produced mixture; and  
controlling a pressure in at least a portion of the formation to control the composition of the produced mixture.

5325. The method of claim 5324, wherein the pressure is controlled by a valve proximate to a location where the mixture is produced.

5326. The method of claim 5324, wherein the pressure is controlled such that pressure proximate to one or more of the heat sources is greater than a pressure proximate to a location where the fluid is produced.

5 5327. The method of claim 5317, wherein an average distance between heat sources is between about 2 m to about 8 m.

5328. A method for treating hydrocarbons in at least a portion of a hydrocarbon containing formation, wherein the portion has an average permeability of less than about 10 millidarcy, comprising:

providing heat from one or more heat sources to the formation;

allowing the heat to transfer from one or more of the heat sources to a selected section of the formation such that heat from the heat sources pyrolyzes at least some hydrocarbons within the selected section, and wherein heat from the heat sources vaporizes at least a portion of the hydrocarbons in the selected section; and

producing a mixture comprising hydrocarbons from the formation.

5329. The method of claim 5328, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from at least the two heat sources pyrolyzes at least some hydrocarbons within the selected section of the formation, and wherein superposition of heat from at least the two heat sources vaporizes at least the portion of the hydrocarbons in the selected section.

5330. The method of claim 5328, further comprising allowing heat to transfer from at least one of the heat sources to the selected section to create thermal fractures in the formation, wherein the thermal fractures substantially increase the permeability of the selected section.

5331. The method of claim 5328, wherein the heat is provided such that an average temperature in the selected section ranges from approximately about 270 °C to about 375 °C.

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5332. The method of claim 5328, wherein at least one of the heat sources comprises an electrical heater located in the formation.

5 5333. The method of claim 5328, wherein at least one of the heat sources is located in a heater well, and wherein at least one of the heater wells comprises a conduit located in the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

10 5334. The method of claim 5328, wherein at least some of the heat sources are arranged in a triangular pattern.

15 5335. The method of claim 5328, further comprising:  
monitoring a composition of the produced mixture; and  
controlling a pressure in at least a portion of the formation to control the composition of the produced mixture.

20 5336. The method of claim 5335, wherein the pressure is controlled by a valve proximate to a location where the mixture is produced.

25 5337. The method of claim 5335, wherein the pressure is controlled such that pressure proximate to one or more of the heat sources is greater than a pressure proximate to a location where the mixture is produced.

30 5338. The method of claim 5328, wherein an average distance between heat sources is between about 2 m to about 8 m.

5339. A method for treating hydrocarbons in at least a portion of a hydrocarbon containing formation, wherein the portion has an average permeability of less than about 10 millidarcy, comprising:

providing heat from one or more heat sources to the formation, wherein at least one of the heat sources is located in a heater well;

allowing the heat to transfer from one or more of the heat sources to a selected section of the formation such that heat from the heat sources pyrolyzes at least some hydrocarbons within the selected section, and wherein heat from the heat sources pressurizes at least a portion of the selected section; and

producing a mixture comprising hydrocarbons from the formation, wherein the mixture is produced from one or more heater wells.

5340. The method of claim 5339, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from at least the two heat sources pyrolyzes at least some hydrocarbons within the selected section of the formation.

5341. The method of claim 5339, further comprising producing fluid from at least one heater well in which is positioned the heat source of the one or more heat sources.

5342. The method of claim 5339, further comprising allowing heat to transfer from at least one of the heat sources to the selected section to create thermal fractures in the formation, wherein the thermal fractures substantially increase the permeability of the selected section.

5343. The method of claim 5339, wherein the heat is provided such that an average temperature in the selected section ranges from approximately about 270 °C to about 375 °C.

5344. The method of claim 5339, wherein at least one of the heat sources comprises an electrical heater located in the formation.

5345. The method of claim 5339, wherein at least one of the heat sources is located in a heater well, and wherein at least one of the heater wells comprises a conduit located in



the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

5346. The method of claim 5339, wherein at least some of the heat sources are arranged in a triangular pattern.

5347. The method of claim 5339, further comprising:  
monitoring a composition of the produced mixture; and  
controlling a pressure in at least a portion of the formation to control the composition of the produced mixture.

5348. The method of claim 5347, wherein the pressure is controlled by a valve proximate to a location where the mixture is produced.

5349. The method of claim 5347, wherein the pressure is controlled such that pressure proximate to one or more of the heat sources is greater than a pressure proximate to a location where the mixture is produced.

5350. The method of claim 5339 wherein an average distance between heat sources is between about 2 m to about 8 m.

5351. A method for treating hydrocarbons in at least a portion of a hydrocarbon containing formation, wherein the portion has an average permeability of less than about 10 millidarcy, comprising:

providing heat from one or more heat sources to the formation;  
allowing the heat to transfer from one or more of the heat sources to a selected first section of the formation such that heat from the heat sources creates a pyrolysis zone wherein at least some hydrocarbons are pyrolyzed within the first selected section; and  
allowing the heat to transfer from one or more of the heat sources to a selected second section of the formation such that heat from the heat sources heats at least some

hydrocarbons within the selected second section to a temperature less than the average temperature within the pyrolysis zone; and

producing a mixture comprising hydrocarbons from the formation.

5 5352. The method of claim 5351, wherein the one or more heat sources comprise at least two heat sources, and wherein superposition of heat from the at least two heat sources pyrolyzes at least some hydrocarbons within the selected first section of the formation, and wherein superposition of heat from the at least two heat sources heats at least some hydrocarbons within the selected second section to a temperature less than the average temperature within the pyrolysis zone.

10 5353. The method of claim 5351, wherein at least some heated hydrocarbons within the selected second section flow into the pyrolysis zone.

15 5354. The method of claim 5351, wherein the heat decreases the viscosity of at least some of the hydrocarbons in the selected second section.

20 5355. The method of claim 5351, further comprising allowing heat to transfer from at least one of the heat sources to the selected first section to create thermal fractures in the formation, wherein the thermal fractures substantially increase the permeability of the selected first section.

25 5356. The method of claim 5351, further comprising allowing heat to transfer from at least one of the heat sources to the selected second section to create thermal fractures in the formation, wherein the thermal fractures substantially increase the permeability of the selected second section.

30 5357. The method of claim 5351, wherein the heat is provided such that an average temperature in the selected first section ranges from approximately about 270 °C to about 375 °C.

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5358. The method of claim 5351, wherein the heat is provided such that an average temperature in the selected second section ranges from approximately about 180 °C to about 250 °C.

5 5359. The method of claim 5351, wherein a viscosity of at least some of the hydrocarbons in the selected second section ranges from approximately about 20 centipoise to about 1000 centipoise.

10 5360. The method of claim 5351, wherein at least one of the heat sources comprises an electrical heater located in the formation.

15 5361. The method of claim 5351, wherein at least one of the heat sources is located in a heater well, and wherein at least one of the heater wells comprises a conduit located in the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

20 5362. The method of claim 5351, further comprising:  
monitoring a composition of the produced mixture; and  
controlling a pressure in at least a portion of the formation to control the composition of the produced mixture.

5363. The method of claim 5362, wherein the pressure is controlled by a valve proximate to a location where the mixture is produced.

25 5364. The method of claim 5362, wherein the pressure is controlled such that pressure proximate to one or more of the heat sources is greater than a pressure proximate to a location where the fluid is produced.

30 5365. The method of claim 5361, wherein the pressure in the selected second section is substantially greater than the pressure in the selected first section.

5366. The method of claim 5351, wherein at least some of the heat sources are arranged in a triangular pattern.

5367. The method of claim 5351, wherein an average distance between heat sources in the selected first section is less than an average distance between heat sources in the selected second section.

5368. The method of claim 5351, wherein the heat is provided to the selected first section before heat is provided to the selected second section.

5369. The method of claim 5351, wherein the selected first section comprises at least one production well.

5370. The method of claim 5351, wherein an average distance between heat sources in the selected first section is between about 2 m to about 10 m.

5371. The method of claim 5351, wherein an average distance between heat sources in the selected second section is between about 5 m to about 20 m.

5372. The method of claim 5351, wherein the selected first section comprises a planar region.

5373. The method of claim 5351, wherein at least one row of the heat sources provides heat to the planar region.

5374. The method of claim 5373 wherein a length of a row is between about 75 m to about 125 m.

5375. The method of claim 5372, wherein the planar region comprises a vertical hydraulic fracture.

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5376. The method of claim 5375, wherein a width of the vertical hydraulic fracture is between about 0.3 cm to about 2.5 cm.

5377. The method of claim 5375, wherein a length of the vertical hydraulic fracture is between about 75 m to about 125 m.

5378. The method of claim 5351, wherein at least one ring comprising the heat sources provides heat to the selected first section.

5379. The method of claim 5378, wherein at least one ring comprising the heat sources provides heat to the selected second section.

5380. The method of claim 5378, wherein the ring comprises a polygon.

5381. The method of claim 5378, wherein the ring comprises a regular polygon.

5382. The method of claim 5378, wherein the ring comprises a hexagon.

5383. The method of claim 5378, wherein the ring comprises a triangle.

5384. A method for treating hydrocarbons in at least a portion of a hydrocarbon containing formation, wherein the portion has an average permeability of less than about 10 millidarcy, comprising:

providing heat from three or more heat sources to the formation;

allowing the heat to transfer from three or more of the heat sources to a selected section of the formation such that heat from the heat sources pyrolyzes at least some hydrocarbons within the selected section, and at least three of the heat sources are arranged in a substantially triangular pattern; and

producing a mixture comprising hydrocarbons from the formation.

5385. The method of claim 5384, wherein superposition of heat from at least the three heat sources pyrolyzes at least some hydrocarbons within the selected section of the formation.

5 5386. The method of claim 5384, wherein the mixture is produced from a production well located in a triangular region created by at least three heat sources.

10 5387. The method of claim 5384, further comprising allowing heat to transfer from at least one of the heat sources to the selected section to create thermal fractures in the formation, wherein the thermal fractures substantially increase the permeability of the selected section.

15 5388. The method of claim 5384, wherein the heat is provided such that an average temperature in the selected section ranges from approximately about 270 °C to about 375 °C.

5389. The method of claim 5384, wherein at least one of the heat sources comprises a electrical heater located in the formation.

20 5390. The method of claim 5384, wherein at least one of the heat sources is located in a heater well, and wherein at least one of the heater wells comprises a conduit located in the formation, and further comprising heating the conduit by flowing a hot fluid through the conduit.

25 5391. The method of claim 5384, wherein at least some of the heat sources are arranged in a triangular pattern.

30 5392. The method of claim 5384, further comprising:  
monitoring a composition of the produced mixture; and  
controlling a pressure in at least a portion of the formation to control the composition of the produced mixture.

5393. The method of claim 5392, wherein the pressure is controlled by a valve proximate to a location where the mixture is produced.

5 5394. The method of claim 5392, wherein the pressure is controlled such that pressure proximate to one or more of the heat sources is greater than a pressure proximate to a location where the fluid is produced.

10 5395. The method of claim 5384, wherein an average distance between heat sources is between about 2 m to about 8 m.

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